AN ACOUSTIC STUDY OF STEM PROMINENCE IN HÄN ATHABASCAN

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A

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ABSTRACT

Observations in many studies of Athabascan languages have indicated that the stem syllable displays phonetic prominence, perhaps due to its semantic or structural importance, which is realized through a variety of acoustic means. Features such as voicing, duration, manner of articulation, voice quality, and vowel quality pattern differently in stems and prefixes, both in the diachronic developments of Athabascan phonology as well as in the synchronic, phonetic realizations of individual phonemes. This acoustic study of the Hän language investigates the synchronic realization of this morphological conditioning in fricatives, stops, and vowels, and attempts to unify several different phonological effects into a single theory of stem prominence. The results show that the most regular and predictable of these correlates of stem prominence is the increase in duration of segments in stem onsets (consonants) and nuclei (vowels). Additional variations in features that pattern according to morphological category, such as voicing (in fricatives), voice quality (in ejectives), and vowel quality are considered secondary effects largely influenced by duration.

TABLE OF CONTENTS

Page

Signature Page i

Title Page ii

Abstract iii

Table of Contents iv

List of Figures x

List of Tables xiv

List of Examples xv

Acknowledgements xvi

Chapter 1 Introduction 1

1.1. Background and Literature Review 1

1.2. Hän Language Community 3

1.3. The Classification of Hän Within the Athabascan Language Family 5

1.4. Hän Phonology 7

1.4.1. Consonants 7

1.4.2. Vowels 9

1.4.3. Syllable Structure 10

1.5. Hän Orthography 11

1.6. Phonemic Writing Practices in This Paper 13

1.7. Organization of This Paper 14

Chapter 2 Fricatives **15**

2.1. Background and Literature Review 15

2.1.1. Fricative Voicing 15

2.1.1.1. Fricatives in Verb Stem Onsets Developed Voicing Intervocalically 16

2.1.1.2. Fricatives in Possessed Noun, Adjective, and Postposition Stem Onsets Developed Voicing 16

2.1.1.3. PA /y/ Strengthens to [ž] in Stem Initial Position.................... 17

2.1.1.4. Fricatives in Certain Prefix Onsets Developed Voicing.......... 18

2.1.1.5. Fricatives in Loan Words Further Obscure Morphophonological Conditioning of Voicing 22

2.1.2 Synchronic Realization of Fricative Voicing 23

2.1.2.1. Fricative Voicing in Other Athabascan Languages 23

2.1.2.2. Fricative Voicing in Hän... 25

2.2. Methodology 27

2. 3. Results... 29

2.3.1. Duration 29

2.3.2. Voicing... 33

2.3.3. Intensity.. 46

2.4. Analysis and Discussion 47

2.5. Conclusion 52

Chapter 3 Stops 54

3.1. Pulmonic Stops 54

3.1.1. Background and Literature Review 55

3.1.1.1. Diachronic Obstruentization of Stem Initial /n/ 55

3.1.1.2. Consonant Lengthening in Southern Athabascan 56

3.1.2. Methodology 57

3.1.3. Results 59

3.1.3.1. Nasals (/n/) 59

3.1.3.1.1. Nasal Closure Duration 59

3.1.3.1.2. Nasal Intensity 59

3.1.3.2. Plosives (Non-Affricates, /d/ and /t/) 59

3.1.3.2.1. Plosive Closure Duration 60

3.1.3.2.2. Plosive Voice Onset Time 61

3.1.3.2.3. Plosive Intensity 62

3.1.3.3. Affricates (/č/ and /ǰ/) 62

3.1.3.3.1. Affricate Closure Duration 62

3.1.3.3.2. Affricate Release Duration 62

3.1.3.3.3. Affricate Intensity 64

3.1.4. Analysis and Discussion 64

3.1.4.1. Duration 64

3.1.4.2. Intensity 65

3.1.4.3. Comparison with Previous Literature 65

3.2. Ejectives ... 67

3.2.1. Background and Literature Review ... 68

3.2.1.1. Cross-Linguistic Descriptions of Ejectives ... 68

3.2.1.2. Descriptions of Ejective Variation in Athabascan ... 69

3.2.2. Methodology ... 70

3.2.2.1. Duration of Closure and Release ... 70

3.2.2.2. Voicing Effects and Rise Time ... 71

3.2.3. Results ... 72

3.2.3.1. Closure Duration ... 72

3.2.3.2. Voice Onset Time ... 73

3.2.3.3. Voice Quality ... 74

3.2.3.3.1. Occurrence and Frequency of Vowel Laryngealization ... 76

3.2.3.3.2. Ratio of Laryngealization Duration to Release Duration ... 76

3.2.3.3.3. Rise Time ... 77

3.2.4. Analysis and Discussion ... 78

3.3. Comparison Between Pulmonic Stops and Ejectives ... 82

3.4. Conclusion ... 83

Chapter 4 Vowels ... 84

4.1. Background and Literature Review ... 84

4.1.1. Historical Development of Vowels ... 84

4.1.1.1. Merger of /ə/ in Dawson Hän 85
4.1.2. Synchronic Observations of Hän 85
4.1.2.1. Duration 85
4.1.2.2. Quality 86
4.1.3. Observations in Other Athabascan Languages 88
4.1.3.1. Vowel Lengthening as the Result of Stem Prominence 88
4.2. Methodology 89
4.3. Results 90
4.3.1. Reduced Vowels (/ə/) 90
4.3.1.1. Duration 90
4.3.1.1.1. Open Syllables 90
4.3.1.1.2. Closed Syllables (CVk) 91
4.3.1.2. Quality 92
4.3.1.2.1. Open Syllables 92
4.3.1.2.2. Closed Syllables (CVk) 93
4.3.2. Full Vowels 95
4.3.2.1. Duration 95
4.3.2.2. Vowel Quality 96
4.4. Analysis 97
4.4.1. Duration 97
4.4.2. Vowel Quality 99
4.5. Conclusion 101

Chapter 5 Discussion 103

5.1. Duration and Stem Prominence 103

5.1.1. Correlates of Duration.. 104

5.2. Contributions of This Study.. 107

5.3. Future Research 108

5.3.1. Stem Prominence and Other Prosodic Systems..................................... 108

5.3.2. Duration and Disyllabic Stems. 109

5.3.3. Multiple Morphological Layers 110

5.3.4. Future Improvements in Methodology 112

5.4. Conclusion 112

Bibliography 113

Appendix.. 119

LIST OF FIGURES

Page

Figure 1.1: Native Languages of Alaska (Krauss 1982)... 4

Figure 1.2: “Development of Tone Systems” from Krauss & Golla 1981:70)............. 7

Figure 2.1: Hän Athabascan Verb Template... 21

Figure 2.1: Mean Duration of Onset Fricatives in Stems vs. Prefixes.......................... 30

Figure 2.2: Mean Duration of Onset Fricatives in Word Initial vs. Word Medial Position 30

Figure 2.3: Average Length of Onset Fricatives in Stems vs. Prefixes for Each Speaker... 31

Figure 2.4: Average Length of Onset Fricatives in Stems vs. Prefixes for Fricatives at Each Place of Articulation 32

Figure 2.5: Stem Onset Word Medial /ð/, *voiced at beginning and a little at the end*: /niðan/ ‘s/he wants’ 34

Figure 2.6: Stem Onset Word Medial /ð/, *voiced throughout*: /niðan/ ‘s/he wants’ 34

Figure 2.7: Stem Onset Word Medial /ð/, *voiced erratically*: /wəðat/ ‘its liver’........... 35

Figure 2.8: Total Voicing Percentage of Onset /ð/ According to Morphological Environment.. 36

Figure 2.9: Total Voicing Percentage of Onset /ð/ According to Phonological Environment.. 37

Figure 2.10: Total Voicing Percentage of Onset /ð/ in Word Medial Position According to Morphological Environment.. 38

Figure 2.11: Total Voicing Percentage of Different Fricatives in Stem Onset Word Medial Position 39

Figure 2.12: Total Percent of Fully voiced Fricatives in Syllable onset Medial Position 40

Figure 2.13: Semi-voiced Medial prefix onset /ð/ example: /nəðəktsąy/ ‘s/he picked’ 41

Figure 2.14: Fully Voiced Medial Prefix Onset /ð/ example: /daðəǰæ/ ‘s/he is sitting’ 42

Figure 2.15: Mean Total Voicing Percentages for Different Speakers in Different Environments 43

Figure 2.16: Realization of /ž/ Before Back Vowels: /žah/ ‘snow’ 44

Figure 2.17: Realization of /ž/ Before Front Vowels: /ǰəžìʔ/ ‘his food’ 44

Figure 2.18: Realization of Stem Onset Word Medial /ð/: /wəðæ̀t/ ‘his mouth’ 45

Figure 2.19: Realization of Stem Onset Word Medial /ð/: /wəðàt/ ‘his liver’ 45

Figure 2.20: Realization of Stem Onset Word Medial /ɣ/: /doɣor/ ‘s/he is playing’ 46

Figure 2.21: Mean Intensity of Word Medial /ð/ According to Morphological Environment for Different Speakers 47

Figure 2.22: Correlation between Duration and Total Voicing Percentage for Stem Onset Word Medial Voiced Sibilants (/z/, /ž/, /zr/) 49

Figure 2.23: Correlation between Voicing and Duration of /ð/ in Word Medial Stem Onset Position 50

Figure 3.1: Comparison of /n/ Closure Duration According to Morphological Category 59

Figure 3.2: Comparison of /d/ and /t/ Closure Duration According to Morphological Category 60

Figure 3.3: Comparison of /d/ and /t/ VOT According to Morphological Category 61

Figure 3.4: Comparison of /ǰ/ and /č/ Total Release Duration According to Morphological Category 64

Figure 3.5: Average Stop Prefix Onset Duration as a Percentage of the Average Stop Stem Onset Duration (With Comparison to S.C. Western Apache (Tuttle 2005)) 67

Figure 3.6: Ejective with Laryngealized Release: *First syllables of* /nit'àðə̀žæ/ 's/he caught up with us.' 71

Figure 3.7: Comparison of Ejective Closure Duration According to Morphological Category 73

Figure 3.8: Comparison of Ejective Release Duration According to Morphological Category 74

Figure 3.9: Weak Type Ejective /t'/ in Prefix Onset: *No gap between burst and laryngealized vowel onset*: /yət'àðə̀žæ/, 'he caught up with her' 75

Figure 3.10: Strong Type Ejective /t'/ in Stem Onset: *Gap between burst and modal vowel onset*: /dot'aw/ 'it is red' 75

Figure 3.11: Comparison of VOT to Laryngealization Proportion for Different Ejective Phonemes 77

Figure 3.12: Comparison of Rise Time According to Morphological Environment for All Ejectives 78

Figure 3.13: Example of a Neither Strong nor Weak Ejective: *Beginning syllables of nač'əʔə̀w 's/he is eating'* 79

Figure 3.14: /k'/ Closure Duration to Rise Time Correlation 81

Figure 4.1: Comparison of /ə/ Duration in Open Syllables According to Morphological Category 91

Figure 4.2: Comparison of /ə/ Duration in Closed Syllables (CVk) According to Morphological Category 92

Figure 4.3: Comparison of /ə/ Vowel Quality According to Syllabic and Morphological Environment 94

Figure 4.4: Comparison of Full Vowel Duration According to Morphological Environment 95

Figure 4.5: Comparison of F1 of Full Vowels According to Morphological Environment 96

Figure 4.6: Comparison of F2 of Full Vowels According to Morphological Environment 97

Figure 4.7: Lip Rounding in /šahtsə/ 100

Figure 4.8: Lack of Lip Rounding in /hodək/ 100

Figure 5.1: Percent Length of Prefix Segments Compared to Stem Segments 104

Figure 5.2: Duration Differences between Disyllabic Stem and Polymorphemic Word 110

LIST OF TABLES

Page

Table 1.1: Hän Consonants 8

Table 1.2: Hän Vowels 10

Table 1.3: Hän Schwa Deletion 11

Table 1.4: Comparison Between Alaskan and Canadian Orthographies 13

Table 2.1: Reflexes of Prefixes with Historically Voiced Fricative or Approximant Onsets 20

Table 2.2: Prefixes with Voiceless Fricative Onsets 20

Table 2.3: Phonetic Correlates of Fortis and Lenis Fricatives, (from Holton 2000) 24

Table 2.4: Fricative Environments in Hän 29

Table 3.1: Hän Nasal Obstruentization 55

Table 3.2: Strong vs. Weak Ejectives, (from Ham 2008) 69

Table 3.3: Percentage of Ejective Tokens Followed by Significant Vowel Laryngealization 76

Table 3.4: Correlation between Closure Duration and Rise Time 80

Table 4.1: Reflexes of PA Vowels in Modern Hän (from Krauss & Golla 1981) 85

Table 4.2: Vowel Duration in Various Syllable Types (after Ritter 1978b) 86

Table 4.3: Descriptions of Hän /ə/ in Different Syllable Types 88

LIST OF EXAMPLES

Page

(2.1) Environments of Hän Voiced Fricatives in Verb Stems 16

(2.2) Environments of Voiced Fricatives in Noun Stems, Adjectives, and Postpositions 17

(2.3) Development of PA *y 17

(2.4) Evidence of Semi-Voiced Fricatives in Shinen (1958)....................................... 26

(4.1) Examples of Stress in Hän 99

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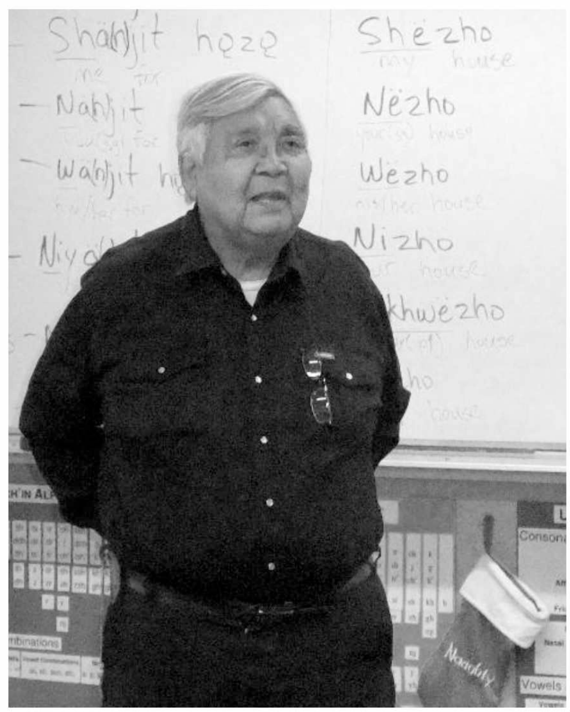
Ruth Ridley and her beadwork at her home in Fairbanks, AK.

Percy Henry speaking at a Hän literacy session at the Yukon Native Language Center in Whitehorse.

Photo courtesy of the Yukon Native Language Centre, Whitehorse, Yukon



Chapter 1 Introduction

1.1. Background and Literature Review. Athabascan scholars have for some time been well-aware of the morphological dichotomy between prefixes and stems (Hoijer 1971). Athabascan languages display a combination of agglutinative and polysynthetic morphology, and have three word classes: nouns, verbs, and particles. Nouns and verbs must consist of at least one stem, which usually contains the lexical content of the word. Athabascan nouns display simpler morphology, and may be formed by adding just a few prefixes, or none at all, to a stem. Verbs, on the other hand, are highly complex and may take between one and a dozen or more prefixes. A few suffixes exist in Athabascan languages but are much less common. In the Hän language, the focus of this study, suffixes are only vestigial, and thus are not addressed.

In addition to these basic grammatical and syntactic differences between stems and prefixes, scholars have also observed that these two categories often pattern differently in their phonology (Leer 1979). This stem versus prefix dualism has conditioned a number of historical, diachronic developments in phonology. While phonological environments such as word initial or intervocalic are often the source of fortition, lenition, or some sort of prominence or weakness in many languages, morphological categories have played a larger role in phonological conditioning in Athabascan. Athabascan languages violate what might be a misconception about typical environments for fortition and weakening, in that there is a high frequency of weak segments (like voiced fricatives and approximants) in word initial position and strong segments (like stops and fricatives with long duration) are often found intervocalically. It may be no surprise that such a phenomenon would be found in a prefixing language like Athabascan, where morphologically weaker prefixes would quite commonly be found in word initial position. For example, the phoneme that could be referred to as a generic labial, /W/, occurs as an approximant [w], in Hän prefixes, and a voiced [b] or voiceless [p] (depending on the speaker) in stem onset position. Additionally, the historical proto-Athabascan phoneme *y remained [y] in prefixes but strengthened to [ž] in Hän stem onsets.

In addition to this historical patterning (more details of which are described in the §2.1.1., §3.1.1.1., and §4.1.1.), many scholars have described Athabascan stems as displaying prominence or some sort of stress within words. For example, Kari (1990) states in his description of Ahtna phonology that stress "is placed on the rightmost stem within a word," (17) indicating some sort of prominence. Likewise, Tuttle (1998) states that prominence is assigned to stems along with heavy syllables and those bearing tone in the Salcha dialect of Lower Tanana. Leer (2005) discusses the importance of stress (again, interpreted as a some form of prominence) in the historical development of the stem, while Rice (2005) explores the properties of stems and prefixes in modern Athabascan and how a listener might use those properties to distinguish stems from prefixes.

Other descriptions and studies have observed differences in the realization of various sounds in stems and prefixes. In some cases, these observations indicate morphological prominence without defining it in these terms. For example, Young and Morgan (1987) for Navajo and Bird (2004) for Carrier have described intervocalic consonants (which usually end up being in stem onsets in the examples given) as being particularly long if not geminates. Once again, this almost seems typologically backwards, given that intervocalic consonants tend to weaken, but instead indicates the dominance of morphological conditioning over phonological conditioning in Athabascan languages. On the other hand, Tuttle (1998) describes morphologically conditioned lengthening of vowels and differences in ejective production. Hargus (2007) also finds duration differences in stem and prefix vowel length in Witsuwit'en. Tuttle (2005) directly links stem prominence with duration increases in stops in the San Carlos dialect of Western Apache. Holton (2000) describes the occurrence of semi-voiced fricatives in Tanacross, which pattern somewhat differently according to morphological category. No study, however, has directly addressed all these effects and how they function as part of a single system of stem prominence.

1.2. Hän Language Community. The Hän language was traditionally spoken in a region stretching from eastern Alaska across the Canadian border into the western Yukon. For most of the 20th century until today, the Hän people have lived in two villages: Eagle, Alaska, and Dawson City, Yukon. The Eagle Hän Tribe has between about 100 and 150 members (Ruth Ridley, p.c.), much smaller than the some 1,100 members (*Tr'ondëk Hwëch'in, n.d.*) of the Tr'ondëk Hwëch'in First Nation in Dawson City.

FIGURE 1.1: NATIVE LANGUAGES OF ALASKA (KRAUSS 1982)

Despite this, there are more fluent speakers today in Eagle, Alaska, probably due in large part to the damaging effects of the Klondike Gold Rush and influx of settlers into Dawson City. In Dawson City, there are said to be two fluent speakers who are at least 70 years old. In Eagle, there are between six (de Reuse, p.c.) and a dozen or so speakers reported depending on the source, the youngest of whom are about 60 years old. All of these speakers are also fluent in English, and many can also understand Gwich'in, Han's northern linguistic neighbor. Today, there have been efforts in both locations to revive the language by teaching it in schools and literacy sessions.

1.3. The Classification of Hän Within the Athabascan Language Family.

The Athabascan languages are typically divided into three major geographic groups, the Southern or Apachean languages (including Navajo, Jicarilla, Western Apache, etc.); the Pacific Coast languages of northern California and Oregon (including, Hupa, Mattole, Galice, etc.); and the Northern Athabascan languages of Alaska and northwestern Canada. Although some attempts have been made to divide the Northern Athabascan languages into subfamilies (Hoijer 1963), no such classification has been widely accepted (Krauss & Golla 1981). The Northern Athabascan language group is a prime example of a dialect continuum resulting from the constant interaction between the various tribes and bands. Linguistic innovations spread over dialects and languages and since no language was ever geographically isolated, the family-tree model fails to describe the situation adequately (Krauss & Golla 1981).

Despite this, languages in close proximity tend to share more features. Hän has most often been compared to the Gwich'in language (Hoijer 1963, Krauss & Golla 1981, Krauss 1982) which is spoken directly to the north. Hän and Gwich'in indeed share a great many phonological innovations, including the development of low tone, major consonant shifts, and a thorough neutralization of stem final consonants (Leer 1996). Additionally, most Hän speakers "understand [Gwich'in] fairly well" (Krauss & Golla 1981:77). However, Hän and Gwich'in have undergone a great deal of independent change, and their similarities may be somewhat exaggerated (de Reuse, p.c.). Mutual intelligibility, it seems, is unidirectional, and Gwich'in speakers seem to understand little

Hän. This situation may be the result of Hän speakers' familiarity with Gwich'in, due to its "cultural dominance" (Krauss & Golla 1981:77).

Hän has also been placed in a group of languages known as "Headwaters Athabascan," indicating languages of the upper Yukon such as Hän, Gwich'in, and Northern and Southern Tutchone, with Upper Tanana being "a marginal member" (Leer 1996:3). While not a subfamily with a common ancestor, this group of languages tends to share a number of innovations, including denasalization, the development of light and heavy stems, and the sonorantization of stem-final affricates (Leer 1996). Hän's southern boundary with the Tanana chain (including the Lower Tanana dialects, Tanacross, and Upper Tanana) is said to be more distinct than its northern boundary with Gwich'in. However, there are many characteristics shared between Hän and the Tanana languages, such as the development of stem-initial consonants found in Lower Tanana (Krauss & Golla 1981). The development of contrastive tone is also shared by Hän and most of its neighbors (Gwich'in, Northern Tutchone, Upper Tanana, and Tanacross), although Tanacross and Northern Tutchone developed high tone in the syllables where the rest of the languages, such as Hän, developed low tone. This is not the case for the languages of Western Alaska (Deg Xinag, Holikachuk, Upper Kuskokwim, and all but one dialect of Koyukon, as seen on the map below in figure 1.2) or southern Alaska (Dena'ina and Ahtna) where tone either never developed or was lost (Krauss & Golla 1981).

FIGURE 1.2: "DEVELOPMENT OF TONE SYSTEMS" FROM KRAUSS & GOLLA (1981:70))

Key: I – Deg Xinag (Ingalik), Ho – Holikachuk, Ko – Upper Kuskowim, Ky – Koyukon, Tn – Dena'ina, A – Ahtna, LT – Lower Tanana, TC – Tanacross, UT – Upper Tanana, K – Gwich'in, H – Hän, NT – Northern Tutchone, ST – Southern Tutchone, Hr – Hare, Bl – Bearlake, M – Mountain, Sl – Slavey, D – Dogrib, Chp – Chipewyan, Ka – Kaska, T – Tagish, Ta – Tahltan, Sk – Sekani, Be – Beaver, Ts – Tsetsaut, B – Babine-Witsuwit'en, C – Carrier, S – Sarsi, Ch - Chilcotin

1.4. Hän Phonology. Like other Athabascan languages, Hän has a large phonemic inventory, rich in consonants and with an average number of vowels.

1.4.1. Consonants. The Hän language has between about 40 and 50 consonants depending on dialect and how certain allophones are counted. There are a total of eight places of articulation: labial, dental, lateral, alveolar, retroflex, palatal, velar, and glottal. The lateral series is best described as a place of articulation due to its patterning in

TABLE 1.1: HÄN CONSONANTS

	labial		dental		lateral	alveolar	retroflex	palatal	velar	glottal
voiced	<b> /b/[2]		<d> /d/[3]					<j> /d^3/[3]		
plain			<d> /d/	<ddh> /dð/	<dl> /dɬ/	<dz> /dz/	<dr> /dr/	<j> /ǰ/	<g> /g/	<’> /ʔ/
aspirated			<t> /t/	<tth> /tθ/	<tl> /tɬ/	<ts> /ts/	<tr> /tr/	<ch> /č/	<k> /k/	
ejectives			<t’> /t’/	<tth’> /tθ’/	<tl’> /tɬ’/	<ts’> /ts’/	<tr’> /tr’/	<ch’> /č’/	<k’> /k’/	
voiceless fric.			<th> /θ/		<ł> /ɬ/	<s> /s/	<sr> /sr/	<sh> /š/	<kh> /x/	<h> /h/
voiced fric.			<dh> /ð/		<l> /l/[4]	<z> /z/	<zr> /zr/	<zh> /ž/	<gh> /ɣ/	
voiced sonorants[1]	<w, -ww> /w/[2]	<m> /m/[2]	<n, -nn (-n)> /n/[3]		<l, -ll (-l)[4]> /l/		<r, -rr (-r)> /r/	<y, -yy (-y)> /j/	<ng> /ŋ/	
voiceless sonorants[1]	<hw, -wh> /w̥/		<-n (-nh)> /n̥/		<-l (-lh)> /l̥/		<-r (-rh)> /ɻ̥/	<-y (-yh)> /j̥/		

[1] A dash before a consonant indicates a spelling difference in final position, while parentheses indicate how that spelling differs in Dawson orthography

[2] Often /b/, /w/, /and /m/ are considered allophones of the underspecified phoneme /W/

[3] Often /n/, /d/ and /d^3/ are considered allophones of the underspecified phoneme /N/

Shaded boxes indicate sounds that some speakers lack

Athabascan (having a full series reflecting the other places of articulation), as opposed to a manner of articulation. The stops of the language have a three-way laryngeal distinction: plain (voiceless, unaspirated), aspirated, and ejective (glottalized). There are also two series of fricatives, voiceless, and voiced, as well as voiced and voiceless sonorants. Some speakers have lost the voiceless sonorants, which only appear in syllable codas, while others have only lost the voiceless nasal [n̥]. Some speakers also have a separate set of true voiced stops, although these have merged with the plain stops for others. As with most Athabascan languages, there are curious gaps in the labial series. Hän is also noteworthy for its large number of affricates, and with fifteen it may be tied for the most cross-linguistically (with its neighbor Gwich'in and some Caucasian languages (Hewitt 2010)). Additionally /k/ and /g/ are both phonetically affricates in onsets, usually being pronounced as [kᵡ] and [kʁ] respectively. Affricates are generally considered to pattern with stops, and only in the dental series do both stops and affricates occur.

1.4.2. Vowels. Hän has seven monophthongs (/a/, /æ/, /e/, /i/, /o/, /u/, /ə/) and seven diphthongs (/ay/, /ey/, /oy/, /aw/, /æw/, /ew/, /iw/). Diphthongs may in fact pattern as two separate segments, evidenced by the fact that the final sonorant could also be voiceless (/ey/ vs. /eẙ/). All monophthongs may also display phonemic nasalization, although only the diphthongs /ay/ and /iw/ can be nasalized. In addition, vowels may be unmarked for tone, in which case they display a high pitch, or marked for tone, in which case they are low in pitch, relative to the nearby syllables. Non-phonemic compound tones, rising and falling, can also develop in certain environments. Keep in mind that table 1.2 below shows the vowels phonemically, in relation to one another, and not their precise phonetic descriptions and ranges. For example, /æ/ can range from [æ] to [ɛ] or have a slight schwa offglide, and /a/ can be pronounced as [ɐ] or [ʌ] in closed syllables. /ə/ also may be rounded and less central in stems (see §4.3.1.2. for more details).

TABLE 1.2: HÄN VOWELS

<table>
<tr><th></th><th>Front</th><th>Central</th><th>Back</th></tr>
<tr><td>High</td><td>/i/ <i></td><td rowspan="3">/ə/ <ö>
or <ë></td><td>/u/ <u></td></tr>
<tr><td>Mid</td><td>/e/ <e></td><td>/o/ <o></td></tr>
<tr><td>Low</td><td>/æ/ <a></td><td>/a/ <ä></td></tr>
</table>

Darker shaded boxes indicate a vowel is rounded;

the lighter shading indicates the vowel can be rounded in certain allophones.

1.4.3. Syllable Structure. Hän has a fairly simple syllable structure, occurring as CV(C) for both stems and prefixes. In onsets, all consonants are possible except for /ŋ/ and some voiceless sonorants /ẙ/, /r̥/, /l̥/, /n̥/, and /w̥/ (although /w̥/ may occur in onsets for some speakers and final [l̥] may simply be an allophone of the fricative /ɬ/). /ʔ/ also occurs in stem onsets, although it does not contrast with onset Ø and thus is not usually written in orthography. On the contrary, Hän, like its northern relative Gwich'in, is set apart from the other Alaskan Athabascan languages in its extreme reduction of stem final consonants (Leer 1996). Only the obstruents /k/, /t/, /h/, and /ʔ/ occur in stem final position. All the sonorants may occur in final position, but some, like /w/ and /y/ may be considered part of a diphthong.

Hän can under certain conditions delete schwas, causing scenarios with stem onset consonant clusters not allowed by the underlying syllable structure restraints. An example of this is given below in table 1.3.

TABLE 1.3: HÄN SCHWA DELETION

meaning	Phonemic Form	Phonetic Output
"My father"	/šə.čæ̀ʔ/ →	[ščæ̀ʔ]

1.5. Hän Orthography. The Hän language has two practical orthographies which evolved separately in Alaska and Canada after a writing system was originally established in 1977 by John Ritter and Jeff Leer (Krauss & Golla 1981, Krauss 1983). The Eagle dialect is typically written in the Alaskan orthography, while the Dawson dialect with the Canadian orthography. Both are similar in most representations of vowels and consonants, which are indicated in triangle brackets in tables 1.1 and 1.2.

There are two main differences between the orthographies. First of all, the two sets of stem final sonorants (voiced vs. voiceless), are written differently in each orthography. The Alaskan orthography emphasizes the fact that the voiceless sonorants are shorter in duration than the voiced sonorants, which may actually be about twice as long. Thus, a single letter is used for final voiceless sonorants while double letters are used for final voiced sonorants. The Canadian orthography emphasizes the voicing difference, writing a single letter for the final voiced sonorants and the letter plus an <h> to indicate final voiceless sonorants (which tend not to be present in the Dawson dialect anyway, (Ritter, p.c.), although this <h> is still used when writing the Eagle dialect with the Canadian writing system). The writing of double letters in the Alaskan orthography also extends to vowels, where two letters indicate a longer vowel; these are limited to open stem syllables. Thus, the Canadian system avoids double letters altogether.

The second main difference in orthography is the representation of /ə/. This sound is written as <ë> in prefixes in both dialects and orthographies, and represents a schwa. In open stems, the Alaskan orthography writes <ö> to indicate the central, rounded quality of the vowel. This vowel has more or less merged with /a/ in stems in the Dawson dialect, although it is unclear whether it has merged with /i/ before /k/ in stems (de Reuse, p.c.). When it is written in stems, however, it is also written as <ë>. Thus, <ö> is never written in the Canadian orthography. Comparison of the two writing systems is seen in table 1.4.

Both Hän orthographies also utilize a few diacritics. The ogonek is used to represent nasalized vowels, such as <ą>. Tone is also marked in Hän using diacritics. High tone is the default or unmarked tone, while low tone is considered “marked” and is denoted with a grave accent, such as <à>. Hän vowels can also have compound tones such as rising or falling and are marked with a haček and a circumflex accent respectively: <ǎ> and <â>.

TABLE 1.4: COMPARISON BETWEEN ALASKAN AND CANADIAN ORTHOGRAPHIES

Alaskan	Canadian
-w	-wh
-ww	-w
-y	-yh
-yy	-y
-r	-rh
-rr	-r
-l	-lh
-ll	-l

Alaskan	Canadian
-ää	-ä
-aa	-a
-ee	-e
-ii	-i
-oo	-o
-uu	-u
-öö	-ë
-ö	-ë

1.6. Phonemic Writing Practices in This Paper. In this paper, neither the Alaskan nor Canadian orthography will be used to represent examples of Hän words. All examples will be written using the modified IPA symbols as seen in tables 1.1 and 1.2. These mainly follow the Americanist tradition of using /č/, /ǰ/, /š/, and /ž/ for the post-alveolar (palatal) affricates and fricatives as well as the Athabascanist tradition of using voiced IPA symbols to indicate the plain, unaspirated voiceless stops and the voiceless IPA symbols to indicate the aspirated stops. That is to say, what is phonemically referred to in this paper as /d/ is phonetically [t] and what is referred to as /t/ is phonetically [t^h]. Additionally, non-palatal affricates are written with two syllables although they pattern as single sounds. Members of the retroflex series are written with an 'r' indicating the retroflex fricative release, so /dr/ would correspond to [ʈʂ] or [ʈʐ] in IPA. For vowels, low tone is indicated by the grave accent mark, such as [à]. Nasalization is written with an ogonek accent, so [ą] corresponds to IPA [ã]. A detailed overview of the Hän orthography system with comparison to IPA and the symbols used in this paper can be found in Appendix A.

1.7. Organization of This Paper. This paper is divided into five sections: an introduction, three studies examining stem prominence for different sets of sounds, and a discussion and conclusion which compares the results of the three studies. The three studies examine fricatives, stops, and vowels separately. Each set of these has fundamentally different acoustic characteristics which result in different possibilities for how each group of sounds can exhibit stress. Fricatives have no complete closure but can be either phonemically voiced or voiceless in Hän, and also display high frequency friction. Oral stops are never voiced in Hän (except by a few speakers who maintain voiced stops that developed from sonorant obstruentization) and have a period of complete closure. The stops chapter is further divided into two sections, the first examining pulmonic stops and the second, ejectives. This is due to the acoustic differences in releases in pulmonic stops and ejectives, as will further be described in §3. Vowels are fundamentally different from both stops and fricatives because they are always voiced, more sonorant, and have vowel quality that results from a clearly defined formant structure. Thus, the unique characteristics of each type of speech sounds result in different acoustic effects that must be investigated separately in separate chapters. Each of these three chapters has its own literature review and background, methodology, results, and analysis.

Chapter 2 Fricatives

The Hän Athabascan language has consistently displayed a variety of morphologically conditioned rules that affect the realization of fricatives in stem onsets differently from those in prefix onsets. Diachronically speaking, Hän developed a phonemic contrast in the voicing of its fricatives due to several processes of phonological and morphological conditioning. Prefix fricatives tended to weaken or not to undergo rules that affected stem fricatives, while stem fricatives become phonetically more prominent. This synchronic study of Hän fricatives investigates phonetic realizations of duration, voicing, and intensity to understand how these features function together as part of a system of stem prominence.

2.1. Background and Literature Review.

2.1.1. Fricative Voicing. Descriptions of Hän phonology have all agreed that the language has two series of fricatives which contrast with respect to voicing (McRoy 1967, Ritter 1978a, Krauss 1983). However, this voicing distinction is conditioned both morphologically and phonologically to such an extent that an argument could be made, perhaps, that the language still only has one underlying series of fricatives. This was in fact the case in proto-Athabascan which at one point contained no voiced obstruents (Krauss 1977:7). Between this stage of the proto-language and modern Hän, a series of fairly clear morphological and phonological processes conditioned fricative voicing, which are outlined in the following sections.

2.1.1.1. Fricatives in verb stem onsets developed voicing intervocalically. As seen in modern Hän, this process conditions voicing or voicelessness of a fricative depending on its phonological environment. When the preceding prefix syllable contains a voiceless coda (limited to /t k h/ in Hän) the verb stem onset fricative occurs voiceless, as seen in the examples in (2.1):

(2.1) Environments of Hän Voiced Fricatives in Verb Stems

a. /nih.θan/ 'I want' /nį.ðan/ 'you want'

b. /ih.sǫ/ 'I am good' /n.zǫ/ 's/he is good'

c. /ək.θaw/ 'I am yawning'

d. /dey.ɣor/ 'I am playing'

Examples (2.1a) and (2.1b) demonstrate the alternation of voicing in fricatives occurring either after an /h/, in which case the fricative is voiceless, or occurring intervocalically in which case the fricative is voiced. (2.1c) shows a voiceless fricative following /k/. There is no voicing alternation in this verb because the stem follows various reflexes of the ł-classifier which always are always realized as voiceless segments. (2.1d) shows the opposite, with a voiced fricative occurring intervocalically and no alternation occurring in verbs with the l-classifier (reflexes of which always occur voiced).

2.1.1.2. Fricatives in Possessed Noun, Adjective, and Postposition Stem Onsets Developed Voicing. When this occurs to nouns with possessive prefixes, the process can be interpreted as entirely phonological due to the fricative being in intervocalic position. Although the presence of stem onset voiced fricatives in adjectives would seem to indicate morphological conditioning, the fact that voiced fricatives also occur in noun compounds (such as ‘dog pack’ (2.2b) as seen below) indicates adjectives in noun phrases also act phonologically like compounded nouns. Thus voiceless fricatives remain primarily in noun phrase initial position in stem onsets:

(2.2) Environments of Voiced Fricatives in Noun Stems, Adjectives, and Postpositions

a. /θaẙ/ ‘belt’ /šəðày/ ‘my belt’

b. /xew̥/ ‘pack’ /šəɣèw/ ‘my pack’ /łąy ɣèw/ ‘dog pack’

c. /ču ðaw/ ‘hot water’

d. /ɣæ̀/ ‘next to’ (postposition)

2.1.1.3. PA /y/ Strengthens to [ž] in Stem Initial Position. This morphologically conditioned development occurred regularly in stem onsets and is a prominent example of stem fortition (an approximant becoming a fricative, or a sonorant becoming an obstruent). Thus we have the following historical changes occurring:

(2.3) Development of PA *y

PA (from Krauss 2005)		Hän
*yəχs ‘snow’	>	[žah]
*yəχ ‘house’	>	[žo]

Prefixal /y/, such as in /yə/- (4th person singular object prefix), remains a sonorant. However, [ž] occurring in stem onsets would ostensibly give the language a voicing contrast in the same morphological environment, since Hän stems can contain the voiceless palatal fricative /š/ as an onset. We could maintain, however, that the underlying phoneme is still /y/ which is morphologically conditioned in the stem onset position, although this fact, along with additional voicing innovations, makes the claim that Hän has no voiced fricatives increasingly difficult to support[1].

2.1.1.4. Fricatives in Certain Prefix Onsets Developed Voicing. This process seems to have been conditioned morphologically, since voicing developed in these prefixes in either initial or medial (intervocalic) position. Furthermore, voiced fricatives only occur in certain prefix onsets. Obstruent voicing developments after the proto-Athabascan stage "took on more independence" (Krauss 1977:8) and it is difficult to determine a set rule for why some prefix onset fricatives became voiced while others did not. However, it seems that prefixes closer to the stem (or further to right in the verb template), which in Athabascan languages tend to be more inflectional or grammatical prefixes (Rice 2000), became voiced while those further from the stem or further to the left in the verb template), which are typically more derivational or lexicalized prefixes, remained voiceless.

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1 There are some words such as the yes-no question marker*/ya/* that have onset /y/ (de Reuse, p.c.), however it is unclear if such words are stems, prefixes, or particles of some sort, and such classification is not addressed in this paper.

In addition, other processes of lenition occurred to these same prefix fricatives which developed voicing. The voiced version of /ɬ/ in stem onset word medial position remains a fricative, and thus is phonetically [ɮ]; however where voicing developed in prefixes this phoneme became the voiced lateral approximant [l]. The fricative /x/ historically developed voicing in certain prefixes (such as the gh-perfective and progressive prefixes), however it not only weakened but was deleted altogether. This pattern is very similar to that of what we saw in §2.1.1.3. whereby /y/ strengthens in stem onset position to become a fricative and remains a sonorant in prefixes. Although not a fricative, the Proto-Athabascan phoneme /w/ also patterns similarly, strengthening all the way to a stop [b] (fully voiced for some speakers), but remains a sonorant and approximant in prefix onset position. The alveolar and retroflex fricatives do not seem to occur in any prefixes. Thus, the only phonetically and phonemically voiced fricative that occurs in prefix onsets is /ð/, although it could perhaps be considered a sonorant phonologically based on its patterning (a similar phenomenon occurs in stem final segments in the Arctic Red River dialect of Gwich'in, see Leer 1996:4). Thus table 2.1 and 2.2 below show examples (or reflexes) of voiced fricatives in prefix onset position and then examples of prefixes with voiceless fricatives.

The Athabascan verbal template is divided into several zones, most notably the disjunct and conjunct zones which are known to govern different phonological patterning

TABLE 2.1: REFLEXES OF PREFIXES WITH HISTORICALLY VOICED FRICATIVE OR APPROXIMANT ONSETS

/ð/	stative	/ðəǰæ/ ‘s/he is sitting’
	dh-perfective	/nəðəktsąy/ ‘I picked’
/l/	l-classifier	/lək’aw/ ‘the white one’
	lexicalized prefix	/kəlahdre/ ‘ant,’ ‘spider’
/ɣ/	gh-perfective	/iʔàwʔ/ ‘I ate’
	progressive	/ihhæw/ ‘I am going’
/y/	4th person object marker	/yənihθan/ ‘I want it’

TABLE 2.2: PREFIXES WITH VOICELESS FRICATIVE ONSETS

/ɬ/	reciprocal object marker	/ɬəhùjìk/ ‘they married each other’
/x/	2nd plural object marker	/xwək’ànohčæ/ ‘s/he looks after you all’
	disjunct derivational prefix	/xat’ah/ ‘s/he is cutting it off’
/š/	1st singular object marker	/šənohʔį/ ‘s/he sees me’

rules for their respective prefixes (Kari 1989, Rice 2000). It would be convenient, based on these prior observations, to be able to say that onset fricatives in disjunct prefixes remained voiceless while those in conjunct prefixes became voiced and underwent lenition; however, this is not quite the case as the object pronouns are placed within the conjunct zone. However, they are placed the furthest to the left within the conjunct zone, while the mode, conjugation, subject markers, etc., are to the right, as seen in figure 2.1. The fourth person marker remains in its weaker, voiced form despite being fairly close in the template to the object markers. We could perhaps theorize an additional morphophonological boundary somewhere between the object and 4th person object

DISJUNCT			CONJUNCT											
Adverbial	Incorporating	Iterative	Object	Human Plural	4^{th} Object	Impersonal	Areal-Qualifier	Inceptive	Gender	Conjugation	Mode	Subject	Classifier	STEM
x(ə)			šə, xwə, ɬə		yə					ð, ɣ (Ø)			lə	
No changes occur to the original historical or underlying fricatives; no phonological alternation (such as intervocalic voicing)										Prefix Weakening (voicing and lenition)				Fortition, Prominence

FIGURE 2.1: HÄN ATHABASCAN VERB TEMPLATE

slots based on this difference in historical voicing developments in fricatives, although it may be simpler to say that no historical phonological changes occurred to the original onset fricatives in prefixes to the left of the conjugation zone. The underlying, voiceless forms of these fricatives remain in the object pronouns, and the /y/ in the 4^{th} person object pronoun is likewise the historical form (from PA *y), as we know fortition of [ž] occurred in stems. The more grammatical tense, mode, and classifier fricatives became voiced and weakened. This might also explain not only why Proto-Athabascan *w remains as /w/ in Hän prefixes, despite being in the object slot (although it simply might be patterning differently from the fricatives), as well as the fact that voiceless fricatives in prefix onsets do not become voiced when in medial, intervocalic position as did the original voiceless fricatives in stem onsets.

In summary, we see how both historical and currently productive processes (such as intervocalic voicing alternations, although §2.1.1.5 shows that this voicing alternation is not applied to borrowings) pattern voicing and lenition in fricatives in the Hän language. Historical processes have caused fricatives in certain prefixes closer to the stem to become voiced (and often weaker in manner) regardless of the phonetic environment (word initial or medial intervocalic). The productive, conditioned process of voicing (as we see in the alternation between /xew̥/ 'pack'/ and /šəɣèw/ 'my pack') only applies to stem fricatives, while prefix fricatives never alternate in voicing according to phonetic environment.

2.1.1.5. Fricatives in Loan Words Further Obscure Morphophonological Conditioning of Voicing. The addition of loan words from French and English into Hän further blurs the voice conditioning environment of fricatives, and even indicates that voiced fricatives had fully phonemicized before the addition of these loan words despite their (somewhat complicated) predictability. For example, the loan word /zray/, 'rice' likely came from the English 'rice' and demonstrates that the word was adapted to Hän phonotactic constraints: Approximant /r/ is found only in stem final position, not initial, and no fricatives, such as /s/, are allowed in coda position. Thus, initial [r] was replaced by the voiced retroflex fricative, /zr/, and the final /s/ was dropped from the word. However, historically, the voiced fricative /zr/ would not have appeared as the onset of a noun stem (there are no nouns native to the language that begin with /zr/) but the speakers did not apply this historical constraint to loan words. This may suggest that there was a phonemic distinction between /zr/ and /sr/, and it was not a single phoneme that alternated according to morphological and phonological environment. Likewise, Hän has the French loan word /ləsew/ 'salt,' where we might instead expect /s/ to become [z] because of the intervocalic environment by this older voicing alternation, but it does not. The initial approximant [l] (from the French definite article) may also defy this process by not being fortified to a fricative, or is reanalyzed as a prefix. In any case, we are forced to accept that modern Hän has a fully phonemic voice contrast in its fricatives, as the phonological and morphological environments have become too obscured for voicing to be considered predictable.

2.1.2. Synchronic Realization of Fricative Voicing. Beyond phonemic voicing developments, additional allophonic voicing effects occur in the fricatives. Most notable is the occurrence of semi-voiced fricatives. Semi-voicing of fricatives has been described in closely-related neighboring languages such as Tanacross (Leer 1982, Holton 2000) and possibly Upper Tanana (Minoura 1994). Transcriptions of the Hän language (Shinen 1958, de Reuse 2006) provide evidence for this phenomenon as well.

2.1.2.1. Fricative Voicing in Other Athabascan Languages. In a description of Tanacross phonology, Jeff Leer states that "alongside the fully voiceless and the fully voiced fricatives there exists a semi-voiced variant which appears to be phonemically, if not morphologically, contrastive. The semi-voiced fricative begins voiceless and becomes lenis and voiced immediately preceding the vowel" (Leer 1982:8-9). While he claims that this phenomenon "appears at present to be morphologically unpredictable," (pg. 9) he notes that "the fully voiced variants l, dh, gh, and y are exceptional and occur syllable initially only in lexicalized prefixes and postpositions such as the dh-perfective and gh-perfective and postposition *ghah*" (pg. 9). This statement, particularly the observation of voiced and weakened fricatives (thus in some cases approximants) in certain prefixes such as the perfective markers matches the patterning of fricatives in Hän, as described in §2.1.1.4. However, it would seem that according to his analysis, the semi-voiced variants only occur sporadically elsewhere.

The first in-depth study of this phenomenon in Tanacross appears in Holton (2000). Holton finds that certain phonemically voiced fricatives in stem onsets "may be only partially or sporadically voiced, or even in some cases completely voiceless" while in prefix onsets and stem codas they occur as fully voiced allophones (pg. 96). Given the sporadic nature of this voicing, Holton explores the possibility that Tanacross fricatives should be described as having a fortis versus lenis distinction. He uses the model described in Jaeger (1983) to outline the expected correlates of fricatives defined as either 'fortis' or 'lenis.' The resulting chart is reproduced below in table 2.3.

TABLE 2.3: PHONETIC CORRELATES OF FORTIS AND LENIS FRICATIVES, FROM HOLTON 2000:99

	fortis	**lenis**
articulatory	greater force of articulators	less force of articulators
	sharper onsets of following vowels	more gradual onsets of following vowels
glottal	voiceless	fluctuate between voiced and voiceless
timing	longer	shorter
pulmonic	greater air pressure	less air pressure
	higher intensity frication	lower intensity frication

As a result, Holton followed the criteria as defined by this model and measured the duration, voicing percentage, and high frequency intensity of voiced and voiceless fricatives. These results were then compared among voiceless, semi-voiced (stem onset) and voiced fricatives. As it turned out, semi-voiced fricatives were not shorter in duration than voiceless fricatives, as we would expect to find for lenis fricatives according to Jaeger's definition, although fully voiced fricatives were in fact much shorter. However, semi-voiced fricatives did display a lower level of intensity in high frequency frication than their voiceless counterparts, in addition to being erratically voiced, criteria which fit the description of lenis fricatives.

Some descriptions of the fricatives in the Upper Tanana language also may also indicate the existence of semi-voicelessness. Minoura (1994) states that there is "a three-way opposition of fricatives in terms of voice" (pg. 166). In particular he describes the palatal fricatives in the language as including š [ʃ], š^{y} [ʒ^{ʒy}], and š [ʒ^{ʒ}], the last two of which are described as "lenis fricatives." He states, however, that it is unclear whether these two lenis fricatives are phonemically independent.

2.1.2.2. Fricative Voicing in Hän. In reviewing previous transcriptions of the Hän language, we also encounter evidence of semi-voiced fricatives, even if transcribers have not directly referred to them as such. Some of the earliest serious transcriptions of the Hän language are found in Marsh (1956) and Shinen (1958). Marsh's notes are meticulous and the transcriptions of the fricatives match the accepted phonemic forms as found in later dictionaries such as Ritter (1978a). There is no indication from his notes that the voiced fricatives were ever partially voiced (of course it is impossible to know for sure if he failed to hear voicing at that level of precision or if semi-voiced fricatives were simply not present in the speech of the participant(s) with whom he worked). Shinen, on the other hand, makes frequent mistakes in transcribing fricative voicing. These "mistakes," however, are in similar environments to those in which semi-voiced fricatives have been described in Tanacross, and they provide a strong indication that this phenomenon was occurring even a few generations back. Example (2.4) below shows some of these transcriptions compared to the modern accepted forms.

(2.4) Evidence of Semi-Voiced Fricatives in Shinen (1958)

a. [ne**θ**ɛt]	/nə**ð**æ̀t/	'your mouth
b. [ne**x**oʔo]	/nə**ɣ**òʔ/	'your tooth'
c. [nɪ**θ**iuʔ]	/nə**ð**èw/	'your throat'
d. [tš'ə**θ**ət]	/č'ə**ð**at/	'its liver'
e. [ʔu**šž**oʔ]	/wə**ž**o/	'his / her house'
f. [tš'əðəh]	/č'ə**ð**at/	'its liver'
g. [ðitših]	/**ð**ihčį/	'I am sleeping'

In (2.4a-d), Shinen transcribes the phonemically voiced fricatives in the stem onsets with voiceless fricatives. In (2.4e), he writes two symbols for this segment, probably indicating he heard the fricative begin voiceless and then become voiced. In (2.4f) we see a second transcription of 'its liver' this time with a voiced fricative, perhaps demonstrating the erratic nature of fricative voicing. Example (2.4g) shows that Shinen heard voiced fricatives in prefixes.

In more modern transcriptions we have a similar situation. De Reuse’s field notes (2006) are phonetically precise while the researcher was fully aware of the accepted phonemic forms. For verb forms of ‘hunt,’ we find alternations in the voicing of the retroflex fricative in the stem onset, thus: [ná’t^{h}á:ʐ̥^{r}e], [nat^{h}eyž^{r}e], and [na:ðéš^{r}e^{y}] but with a description next to the š^{r} saying ‘note semi-voiceless.’ Thus the first (with a circle beneath indicating some sort of partially voiced quality) and third indicate semi-voicelessness while the second is fully voiced. Likewise we see other representations of semi-voicelessness such as [niθðán] ‘you want’ and [wəx$^{\dot{y}}$ὲ’] ‘his or her hair.’ Thus, although Hän has never been formally described as having semi-voiced fricatives, there is clear evidence for their existence in both older and modern transcriptions.

2.2. Methodology. In this study, 431 examples of fricatives were elicited from four fluent speakers (RR, BU, EB, and PH) of the Hän language. Three of the consultants (RR, BU, and EB) are female and speak the Eagle dialect, while the remaining consultant (PH) is male and speaks the Dawson dialect. All examples of the fricatives were taken from complete words spoken within complete sentences. Recordings were made with a Zoom H4n Handy Recorder using the internal microphone at a sampling rate of 44.1 KHz and a bit depth of 16 bits. Praat version 5.2.13 (Boersma & Weenink 2009) was used for acoustic analysis. When needed, a two-tailed t-test was applied to the data to analyze variance, with a p-value of .05 indicating significance.

Based on the observations of other Athabascan languages (Holton 2000) and Hän field notes (Shinen 1958, de Reuse 2006, 2010, 2011), this study investigates the realization of fricatives in Hän and how they display prominence in stems. Thus, duration, total voicing percentage, and high frequency intensity were measured for both phonemically voiced and voiceless fricatives. Fricative duration was determined by the beginning and end of high frequency turbulence. Some voiced fricatives have approximant-like parts (see §2.3.2), which sometimes complicated this measurement, although there was usually a clear distinction between the approximant and the following vowel (vowel formants appeared darker than those in approximants). Total voicing percentage was calculated by adding the individual durations of voicing and dividing by the total duration; often, phonemically voiced fricatives were voiced at the beginning, end, and sometimes the middle, or any combination of these. The voiced sections of fricatives were sometimes difficult to determine when voicing might gradually fade out, but voicing was determined to end when it no longer audible or visibly present in the lower frequencies of the spectrogram. The high frequency intensity was isolated by running the samples through a high-pass filter, eliminating frequencies below 500 Hz. Intensity was then measured and calculated in Praat as an average over the total duration of the fricative.

Fricatives were measured at all places of articulation as they occur in Hän (dental, alveolar, lateral, palatal, retroflex, and velar) including their approximant counterparts (such as [l] and [y]). With a few rare exceptions, examples of which were not included in this study, Hän fricatives only occur in syllable onset position. Thus, fricative measurements of duration, voicing percentage, and intensity were compared between stems and prefixes, as well as between word initial and word medial position, resulting in four possibilities (the hyphen indicates the boundary between prefixes and the stem), as seen in table 2.4.

TABLE 2.4: FRICATIVE ENVIRONMENTS IN HÄN

Prefix (onset), Word Initial	**C**VCV-CV
Prefix (onset), Word Medial	CV**C**V-CV
Stem (onset), Word Initial	**C**V
Stem (onset), Word Medial	CV-**C**V

Prefix and stem position are expected to provide different environments for the phonetic realization of fricatives, while medial (intervocalic in all cases of voiced fricatives) as opposed to initial position may also have conditioned effects (and certainly did historically, as we saw in stem voicing alternations such in possessed versus non-possessed nouns, §2.1.1.2.). When necessary, measurements were also compared according to speaker and the place of articulation of the fricative.

2.3. Results.

2.3.1. Duration. This study finds that fricatives occurring in stem onsets were consistently much longer in duration than those occurring in prefix onsets. These mean durations were compared between all stem and all prefix examples (disregarding word environment), and between all word initial and all word medial examples (disregarding morphological environment). These results are seen below:

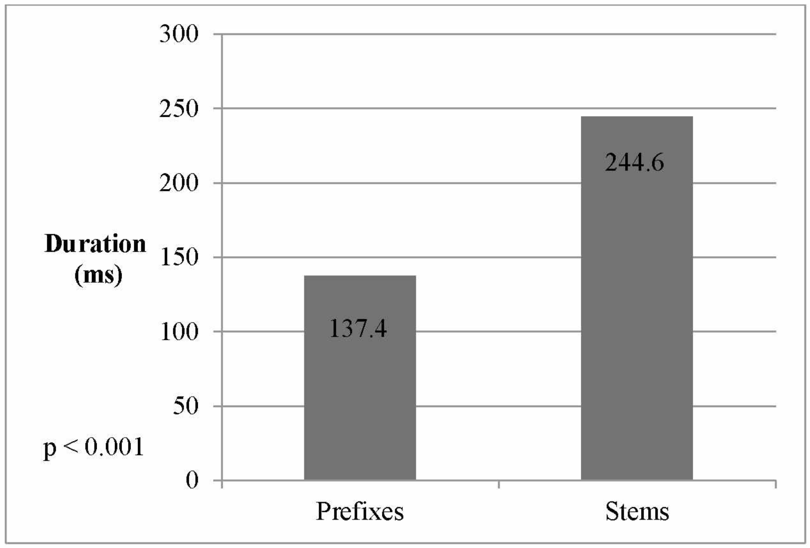


FIGURE 2.1: MEAN DURATION OF ONSET FRICATIVES IN STEMS VS. PREFIXES

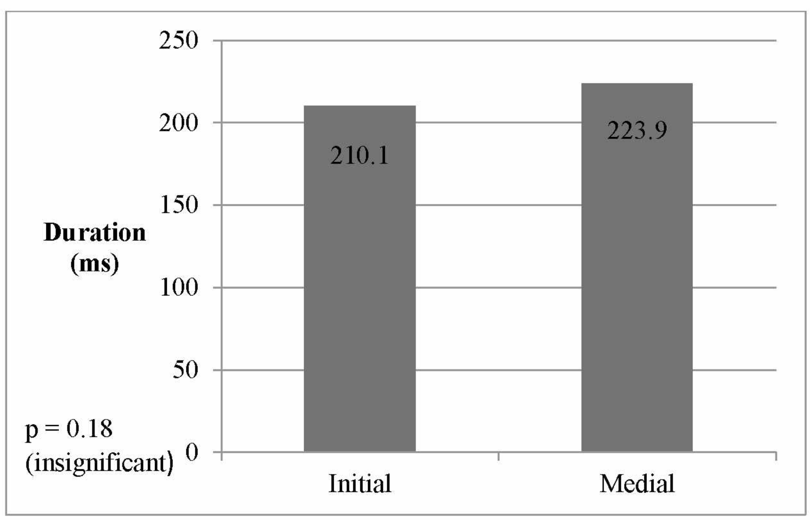


FIGURE 2.2: MEAN DURATION OF ONSET FRICATIVES IN WORD INITIAL VS. WORD MEDIAL POSITION

This data indicates that the phonological environment (word initial or word medial) has little effect on the length of the fricative, yielding an insignificant p value, and the conditioning factor of duration is likely the morphological environment. Figure 2.1 indicates that prefix fricatives are on average about 56.2% the total length of a stem fricative, a meaningful difference. Furthermore, we can compare stem versus prefix differences among each speaker, and among each place of articulation, as seen in the table 2.3 and 2.4 below:

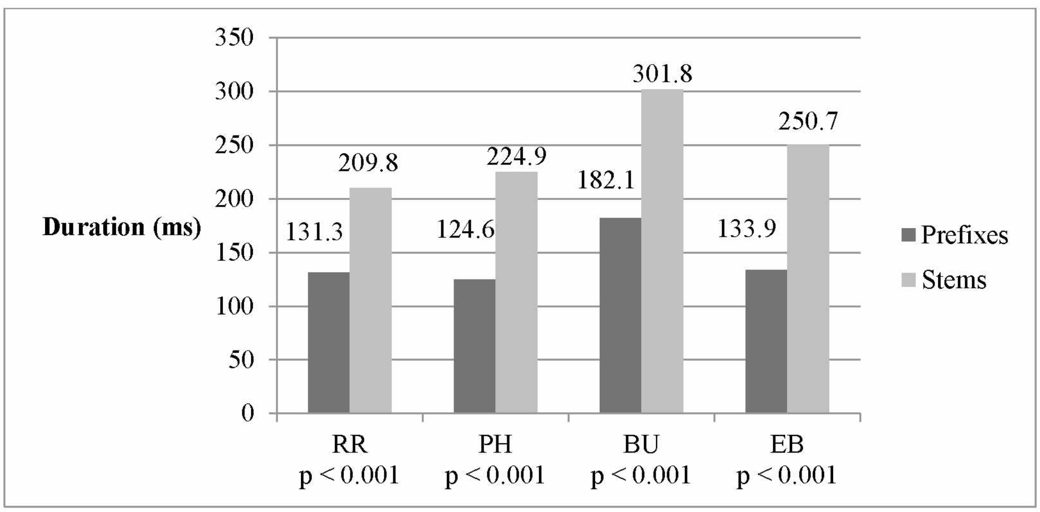


FIGURE 2.3. AVERAGE LENGTH OF ONSET FRICATIVES IN STEMS VS. PREFIXES FOR EACH SPEAKER

For all four speakers, we have a very similar ratio of prefix to stem length, indicating that this difference in fricative length in stems versus prefixes is most likely not idiolectal or dialectal. Figure 2.4 shows that in all cases, the stem variant of the

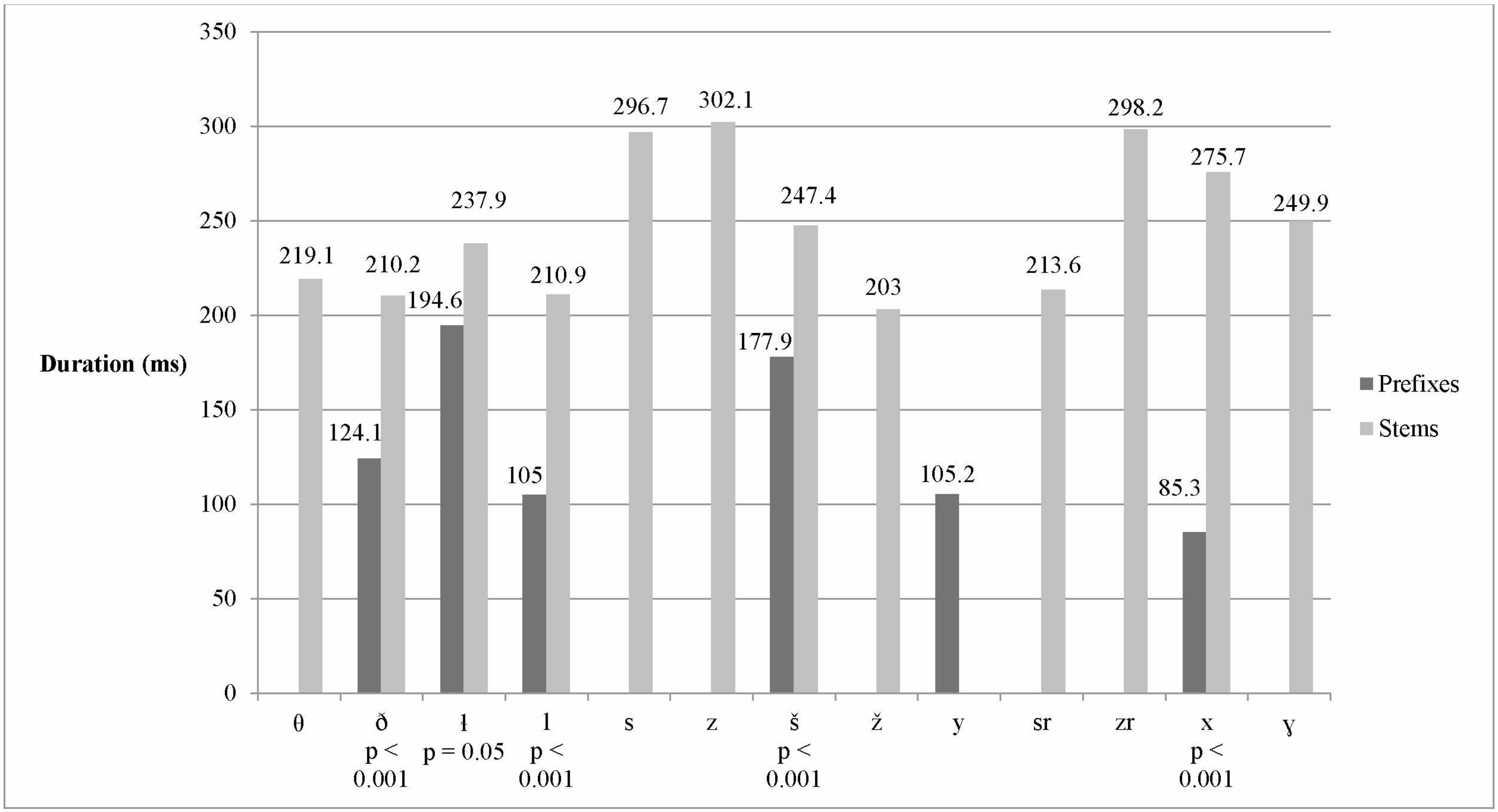


FIGURE 2.4. AVERAGE LENGTH OF ONSET FRICATIVES IN STEMS VS. PREFIXES FOR FRICATIVES AT EACH PLACE OF ARTICULATION

fricative is longer than the prefix variant, although comparisons were only possible for phonemes that occur in both positions (ð, š, x, ɬ). Evidence from §3.1.3.3.2. may indicate that segments in clusters may be shorter, and all examples of /x/ in this data set were clustered with /w/, perhaps skewing the difference. The phoneme /š/ is realized as a cluster in prefixes when the following schwa is deleted, again, possibly affecting the duration. Perhaps the best comparison here would be stem versus prefix /ð/, since the most tokens were elicited and it occurs phonetically as more or less a fricative in both environments (as opposed to /l/, for example, which is an approximant in some prefixes and a fricative in stems, see § 2.1.1.4). For /ð/ the prefix to stem ratio is 59:100 ($p < 0.001$), very similar to the ratios we find in the results for each speaker and in all examples. Thus, the data here firmly indicates that the morphological environment (stem or prefix) has conditioned the duration of onset fricatives, with an average prefix to stem ratio of 56:100 for all speakers.

2.3.2. Voicing. Voicing was much more difficult to quantify meaningfully. First of all, for semi-voiced fricatives, often only the beginning or end was voiced, or the beginning and the end with voicelessness in the middle. For example, out of 53 stem onset word medial /ð/ tokens, 13 were completely voiced, four were voiced only at the beginning, four were voiced only at the end, 30 were voiced a little at the beginning and the end with voicelessness in between, and two were voiced a little at the beginning and the end with a voicing "blip" in the middle. The spectrograms in figures 2.5, 2.6, and 2.7 show some examples of this sporadic nature of voicing.

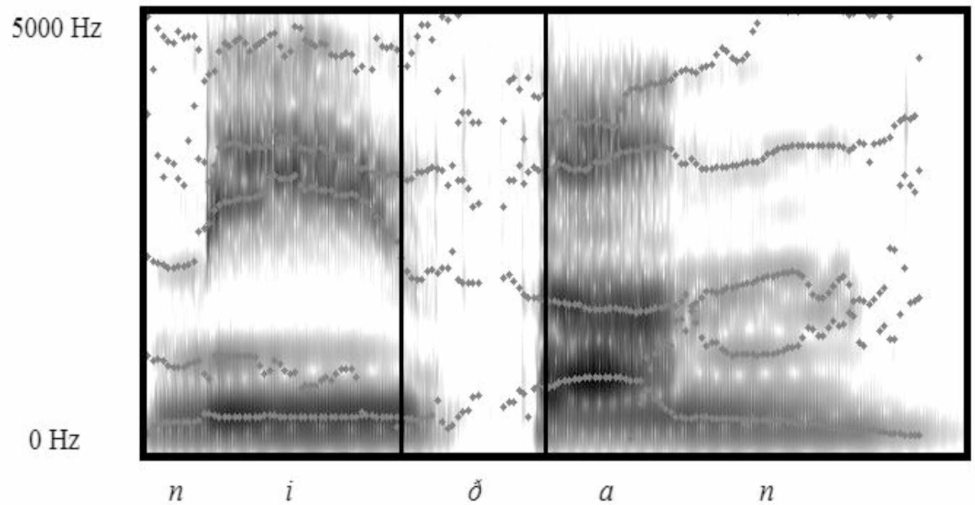


FIGURE 2.5: STEM ONSET WORD MEDIAL /ð/, *voiced at beginning and a little at the end,* /niðan/ ' s/he wants'

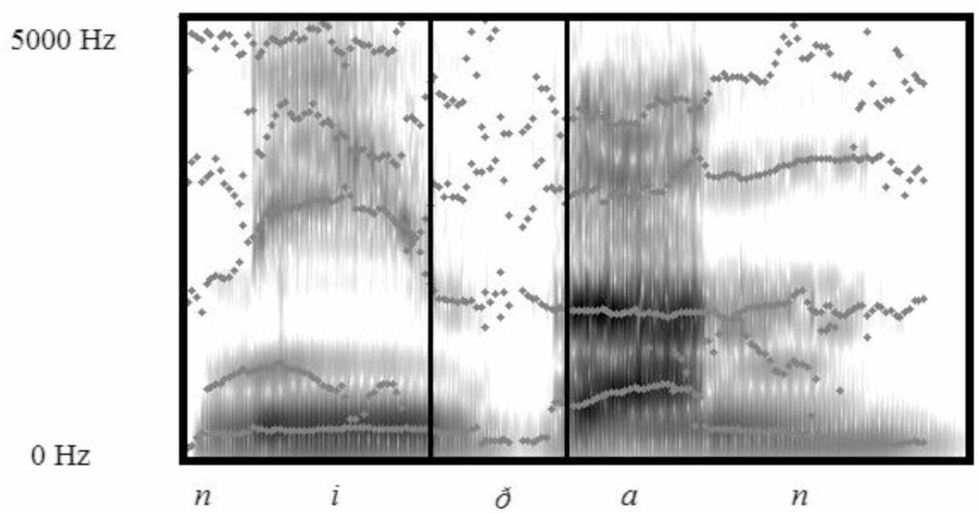


FIGURE 2.6: STEM ONSET WORD MEDIAL /ð/, *voiced throughout,* /niðan/ 's/he wants'

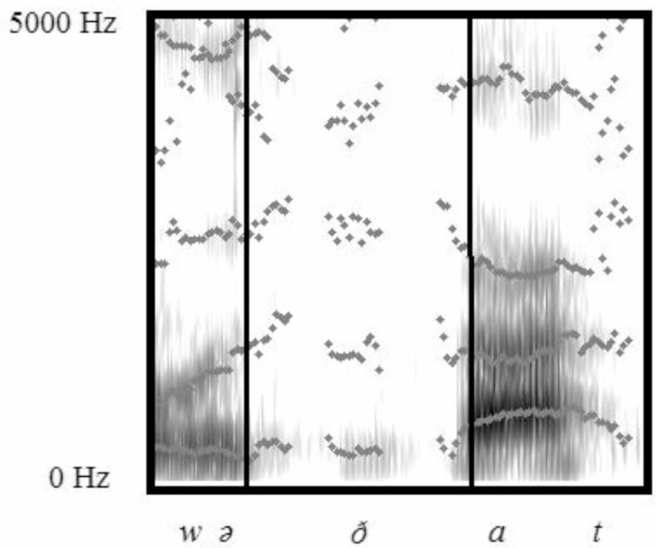


FIGURE 2.7: STEM ONSET WORD MEDIAL /ð/, *voiced erratically,* /wəðat/ ‘its liver’

As a result, the total voicing duration was calculated for each fricative, which was a composite of whatever beginning, end, and middle voicing there might be. This was divided by the total duration of the fricative to determine the total voicing percentage, or what percent of the entire duration of the fricative was voiced.

In order to make a meaningful comparison of voicing as it occurs between the fricatives as they occur in stems and prefixes, only the fricative /ð/ could be considered. The phonemes /z/ and /zr/ do not occur in prefixes, while /l/ occurs as an approximant in prefixes and was always completely voiced. /ž/ alternates with /y/ in stems and prefixes respectively and likewise they differ in manner; /ɣ/ occurred historically but was deleted. Voiceless fricatives never display any sort of voicing and thus would be useless to compare. Thus, only /ð/ occurs as a fricative in both environments.

If we first compare all examples of /ð/ in morphological environment (stem or prefix) and then in phonological environment (word initial or word medial), we find that neither yields a significant difference ($p = 0.08$ and $p = 0.25$ respectively), as seen below in figures 2.8 and 2.9 (Keep in mind that the chart shows total voicing, which is a combination of all voiced sections, and does not necessarily mean the segment began voiced and then ended voiceless).

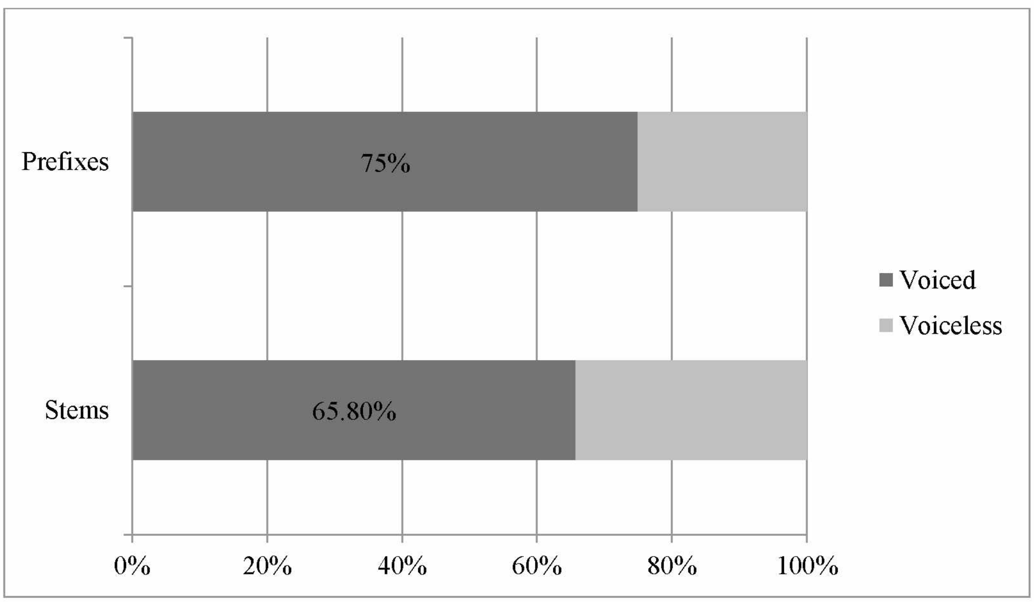


FIGURE 2.8: TOTAL VOICING PERCENTAGE OF ONSET /ð/ ACCORDING TO MORPHOLOGICAL ENVIRONMENT

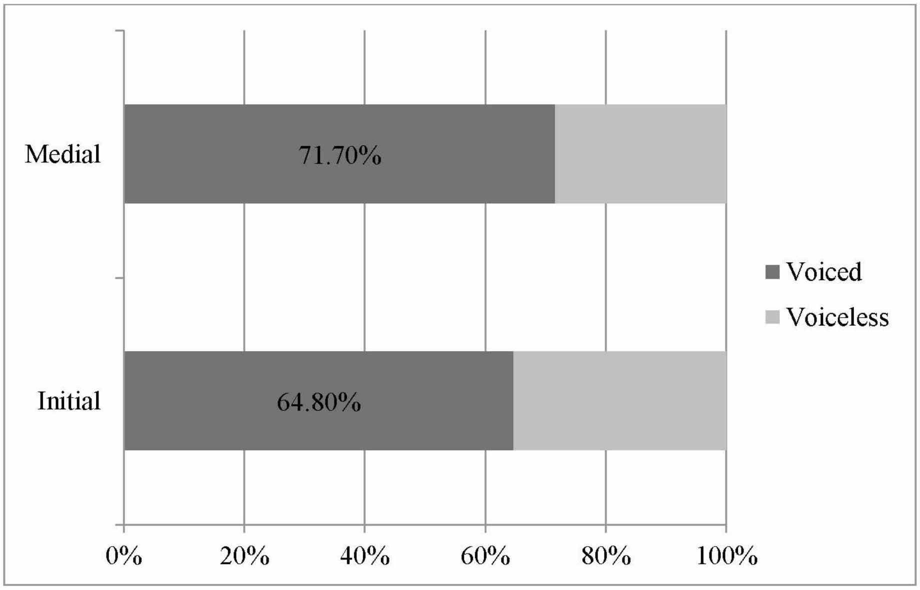


FIGURE 2.9: TOTAL VOICING PERCENTAGE OF ONSET /ð/ ACCORDING TO PHONOLOGICAL ENVIRONMENT

Following the observation of Holton (2000) for the Tanacross language, we would have expected much more voicing of prefix onset fricatives, which were considered to be fully voiced, while stem onset fricatives were considered to be semi-voiced. However, it might be better only to consider word medial position since word initial environment could be causing some voicelessness at the beginning of stem onset and stem prefix fricatives. This data is shown in figure 2.10.

This data shows a significant difference ($p = 0.002$) in voicing as it occurs in stems versus prefixes in word medial position with prefix onset /ð/ averaging 85.8% voiced compared to 66.3% voiced in stem onsets. We might additionally consider the total number of completely voiced examples in each of these positions. For word medial stem /ð/, only 13 of the 53 examples were voiced throughout their entire duration

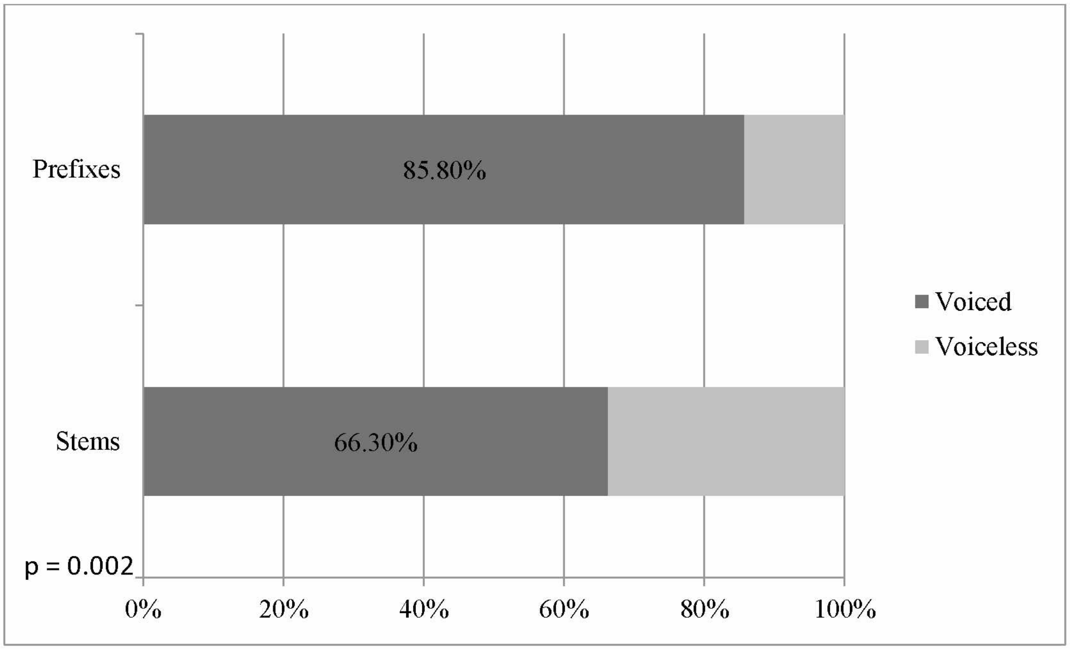


FIGURE 2.10: TOTAL VOICING PERCENTAGE OF ONSET /ð/ IN WORD MEDIAL POSITION ACCORDING TO MORPHOLOGICAL ENVIRONMENT

(24.5%), while for word medial prefix /ð/, 14 of 20 examples were completely voiced (70%). It so happens that it is rare in these examples to find fricatives that are voiced more than 75% or so without being completely voiced, so we should not think that word medial prefix onset /ð/ is typically voiced about 85.8%, but rather that 14 of 20 were completely voiced and that the other 9 were about half voiced on average (52.56% to be exact).

Thus, the results indicate a significant increase in voicing in prefix onset /ð/ in medial position. The chart below shows voicing for all fricatives that occur in stem onset word medial position and shows a similar pattern of semi-voicelessness as also seen with

/ð/. Prefix variants were not included here, as only /ð/ occurs in prefixes as a fricative and the approximants /y/ and /l/ occur completely voiced in all cases.

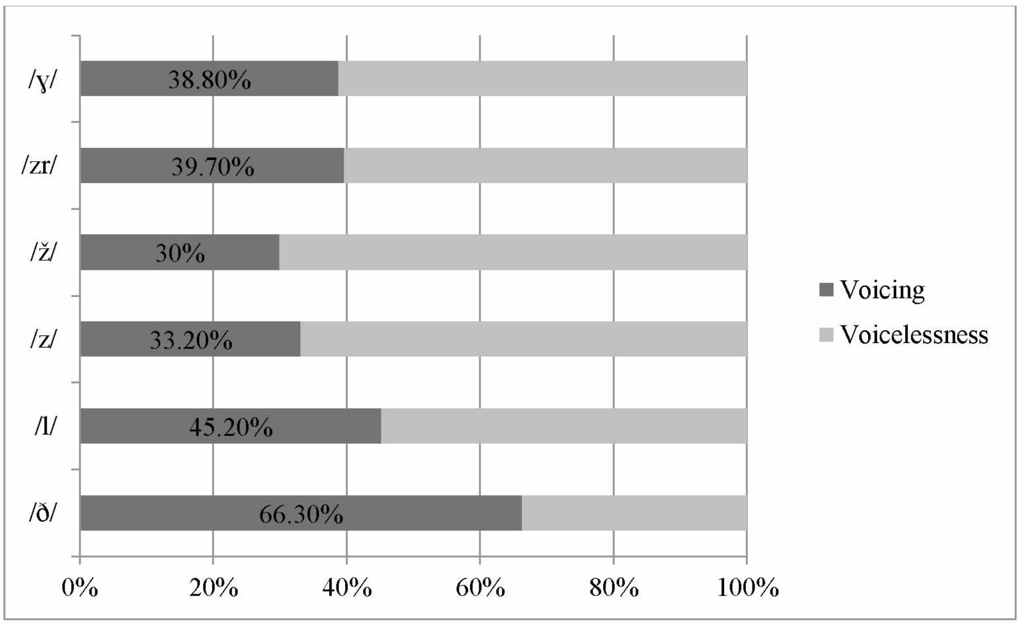


FIGURE 2.11: TOTAL VOICING PERCENTAGE OF DIFFERENT FRICATIVES IN STEM ONSET WORD MEDIAL POSITION

The table in figure 3.12 shows the percent of phonemically voiced onset fricatives that are realized as fully voiced in medial position. Word initial position is once again excluded given that it can sometimes condition a tiny bit of voicelessness at the beginning, but medial position is particularly interesting because it is a typical environment of intervocalic voicing. Here onset approximants are excluded as they were always completely voiced.

This data is particularly interesting, because it also shows a notable difference between the likelihood of different voiced fricatives being fully voiced or just semi-voiced. Almost a quarter of /ð/ examples were fully voiced in stem onset position, while less than 10% of the fricatives in other places of articulation were fully voiced in stems (although there were not enough tokens of the sibilants to say that full voicing never occurs). This likelihood of being fully voiced may correlate with the intensity of

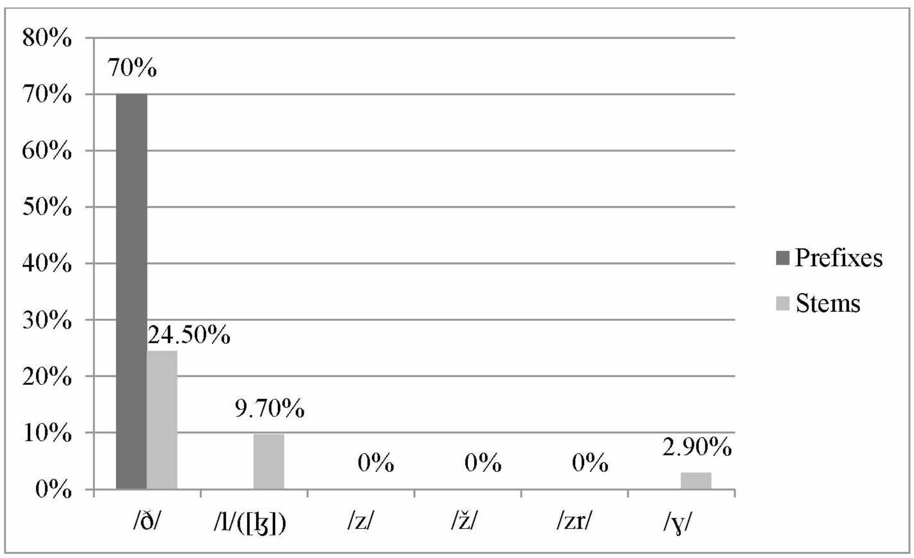


FIGURE 2.12: TOTAL PERCENT OF FULLY VOICED FRICATIVES IN SYLLABLE ONSET MEDIAL POSITION

frication, as sibilants are generally noisier segments, so that the noisier the fricative, the less likely it was to be completely voiced.

While the results do suggest that stem onset fricatives are fairly semi-voiced and prefix fricatives are more voiced, particularly in medial position, these findings differ from those described in Holton (2000) for Tanacross. Even in medial position, there were fairly undeniable examples of semi-voiced /ð/ in prefix onsets, as seen below in

Figure 2.13. It is possible, however, that a voicing distinction of fricatives in stems versus fricatives in Tanacross was highlighted by having other fricatives occurring in prefix position. For example, /ɣ/ occurs in prefix onsets in Tanacross, in addition to /ð/. As we saw above, /ð/ occurred fully voiced in word medial stem onsets far more often than for fricatives in other places of articulation. Thus, if Hän also had prefix onset /ɣ/ and it occurred fully voiced in medial position 70% of the time (like /ð/), its comparison to being fully voiced only 2.9% of the time in medial stem onset positions (as is /ɣ/ in figure 2.12) would yield a much more profound distinction.

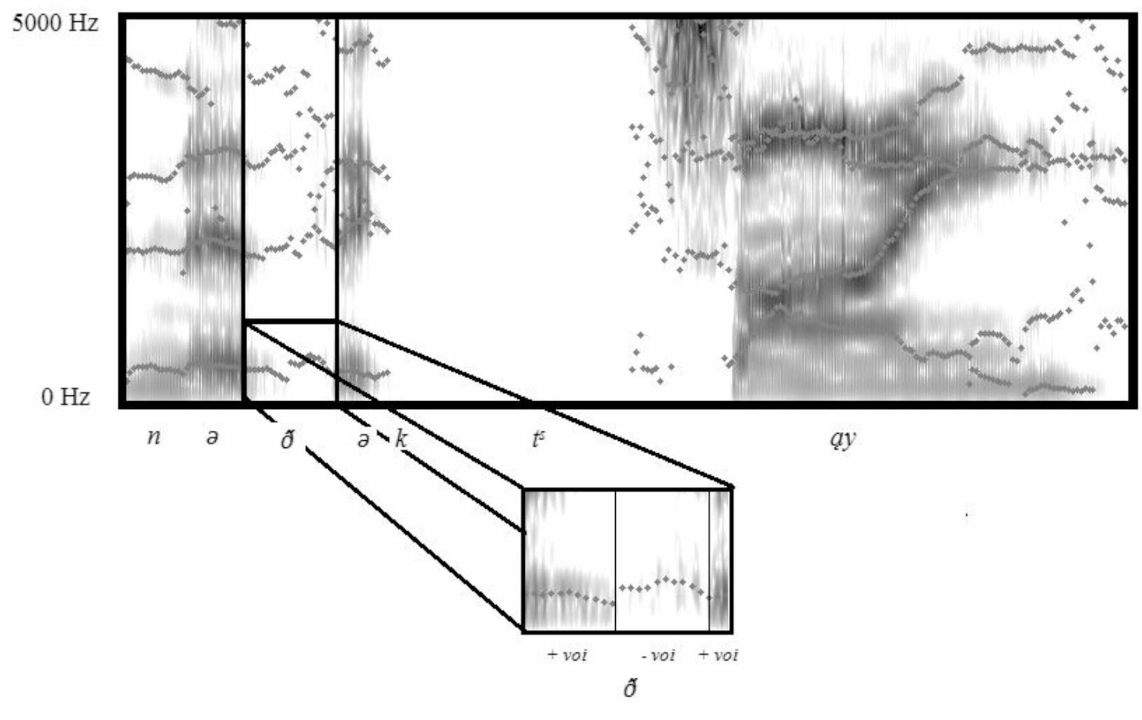


FIGURE 2.13: SEMI-VOICED MEDIAL PREFIX ONSET /ð/ EXAMPLE

/nəðəktsąy/ ‘I picked’

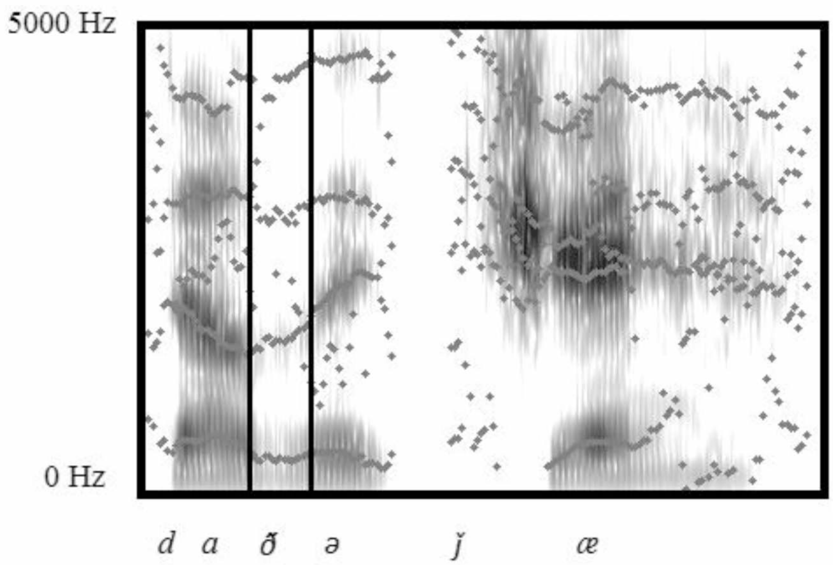


FIGURE 2.14: FULLY VOICED MEDIAL PREFIX ONSET /ð/ EXAMPLE

/daðəǰæ/ ‘s/he is sitting’

Total voicing percentage in fricatives also varied somewhat between speakers in different environments, which may further indicate that the presence or absence of voicing is not a regular morphologically conditioned process but merely has some tendencies along a scale and is also affected by the speaker. Figure 2.15 compares word medial /ð/ in stems and prefixes for three speakers. While prefixes are more voiced in medial position for these three speakers (no word medial prefix onset /ð/ tokens were recorded for the fourth speaker, PH), prefix onset /ð/ was more voiced for RR and BU.

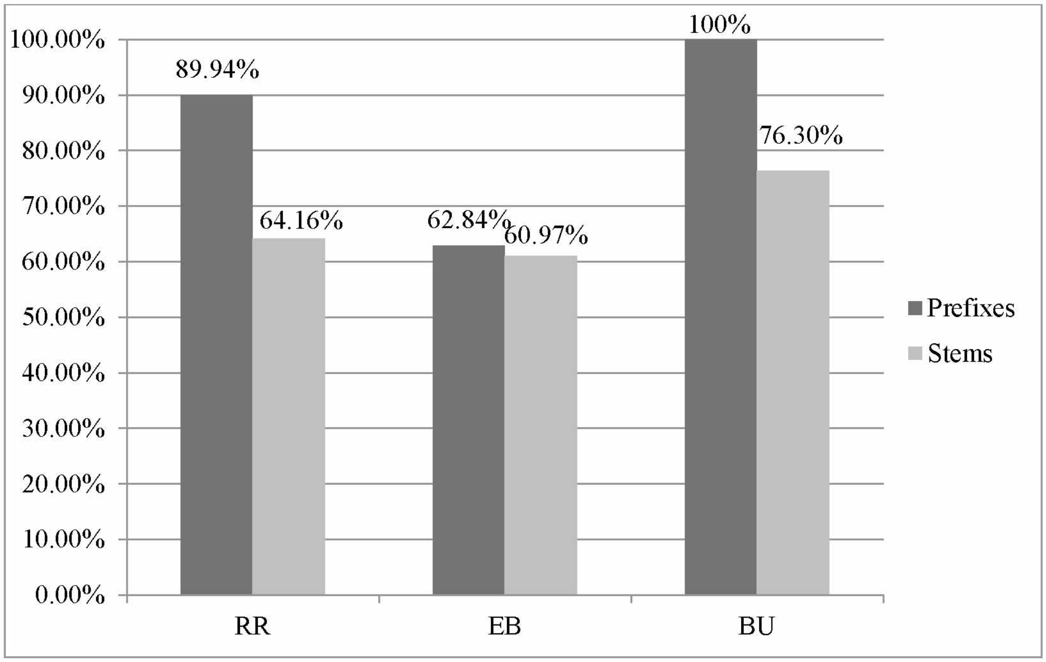


FIGURE 2.15: MEAN TOTAL VOICING PERCENTAGES FOR DIFFERENT SPEAKERS IN DIFFERENT ENVIRONMENTS

Some of the unique characteristics of some of Hän's voiced fricatives should also be noted. For example, /ž/ often had a realization more like [š^{y}] or [š^{žy}], which is similar to what occurs in Tanacross (Holton 2000). The fricative part of the segment was typically voiceless, while it had a voiced, approximant-like off-glide. This was fairly apparent when before back vowels, as below in figure 2.16, but it was less clear when the segment boundary was before front vowels (figure 2.17). This off-glide seemed more apparent than if it were merely the result of formants transitioning from palatal to velar (back vowel) position.

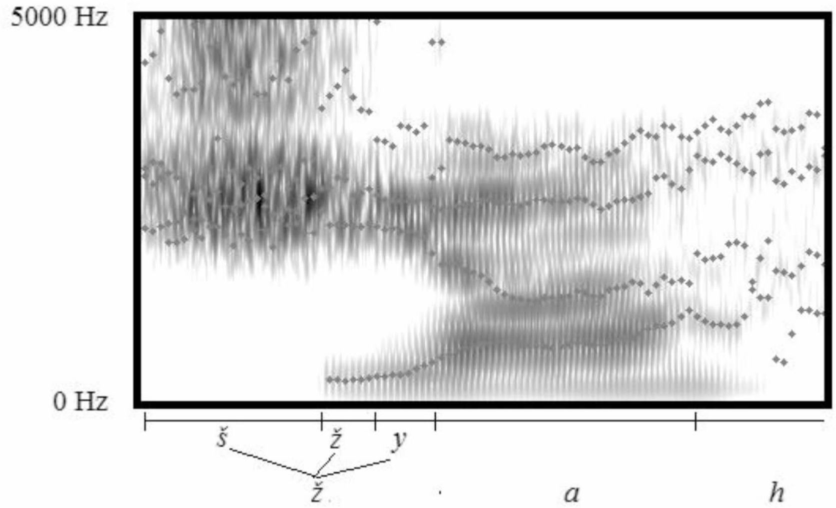


FIGURE 2.16: REALIZATION OF /ž/ BEFORE BACK VOWELS, /žah/ 'snow'

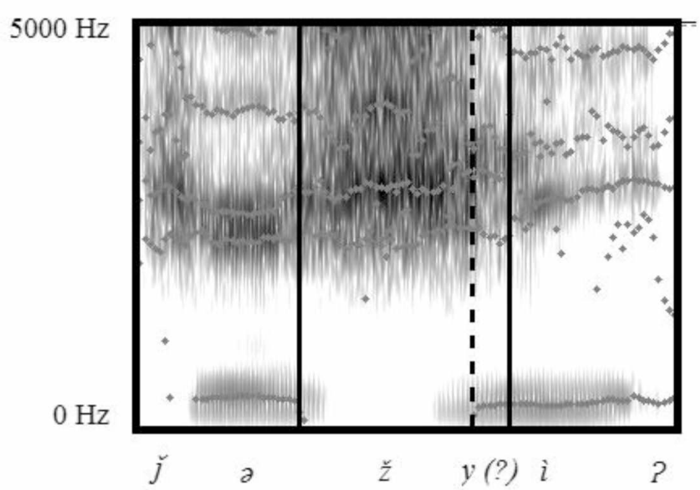


FIGURE 2.17: REALIZATION OF /ž/ BEFORE FRONT VOWELS, /ǰəžìʔ/ 'his food'

Somewhat similarly, semivoiced variants of /ð/ and /ɣ/, especially when in stem onset word medial position, often displayed either an initial voiceless fricative part followed by a voiced and approximant-like part or an initial voiced fricative part followed by a voiced approximant part. This may fit Jaeger's description of lenis fricatives as having a more gradual onset of following vowels, as seen in table 2.3. Examples of these are shown below in figures 2.18, 2.19, and 2.20:

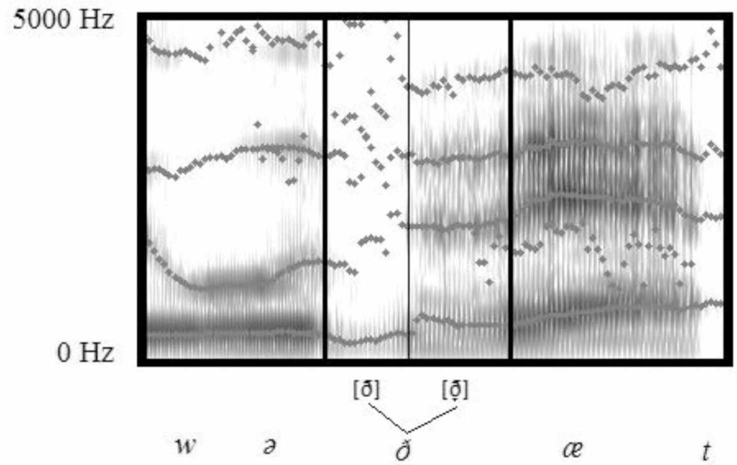


FIGURE 2.18: REALIZATION OF STEM ONSET WORD MEDIAL /ð/, /wəðæ̀t/ 'his mouth'

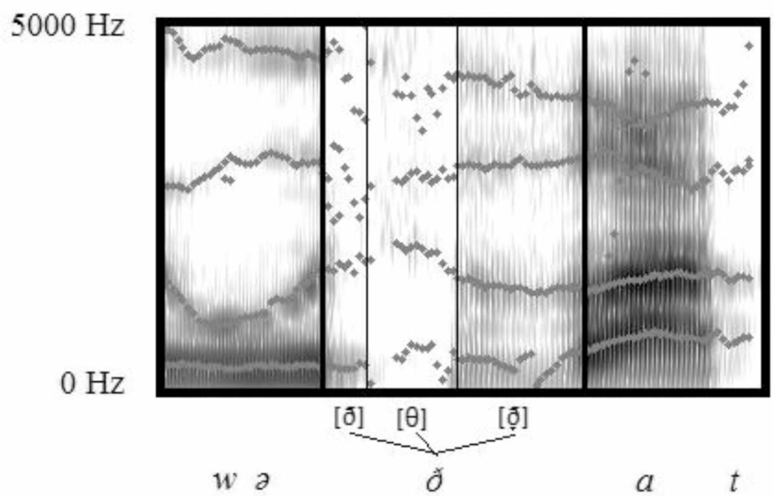


FIGURE 2.19: REALIZATION OF STEM ONSET WORD MEDIAL /ð/, /wəðàt/ 'his liver'

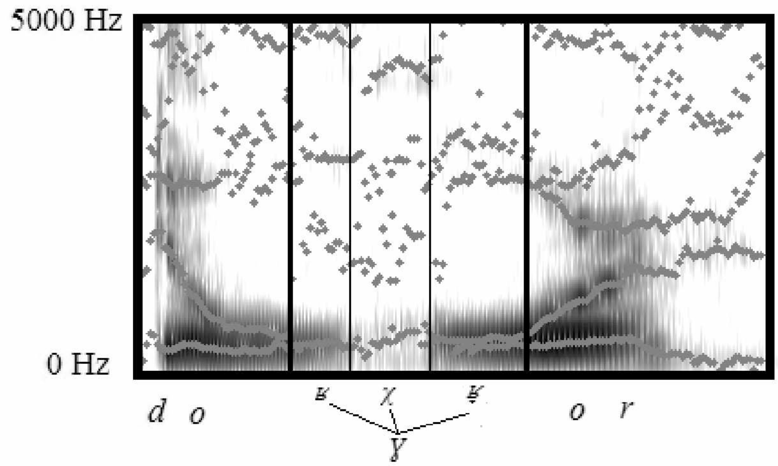


FIGURE 2.20: REALIZATION OF STEM ONSET WORD MEDIAL /ɣ/, /doɣor/ 's/he is playing'

2.3.3. Intensity. Following the methods used in Holton (2000), frication intensity was measured for all fricatives, where frequencies below 500 Hz were removed with a high pass filter. Unlike Holton (2000), in which intensity was measured as a possible distinguishing feature between voiced and voiceless fricatives, the purpose of measuring intensity in this study was to investigate whether there is a difference in intensity between stems and prefixes. Because of the fact that some speakers are expected to be louder than others, and some fricatives are expected to be noisier than others, once again, the best comparison for indicating stem prominence would be among individual phonemes for individual speakers. Additionally, word environment should be controlled just in case. The chart below shows the data comparing the frication intensity of word medial /ð/ for three speakers.

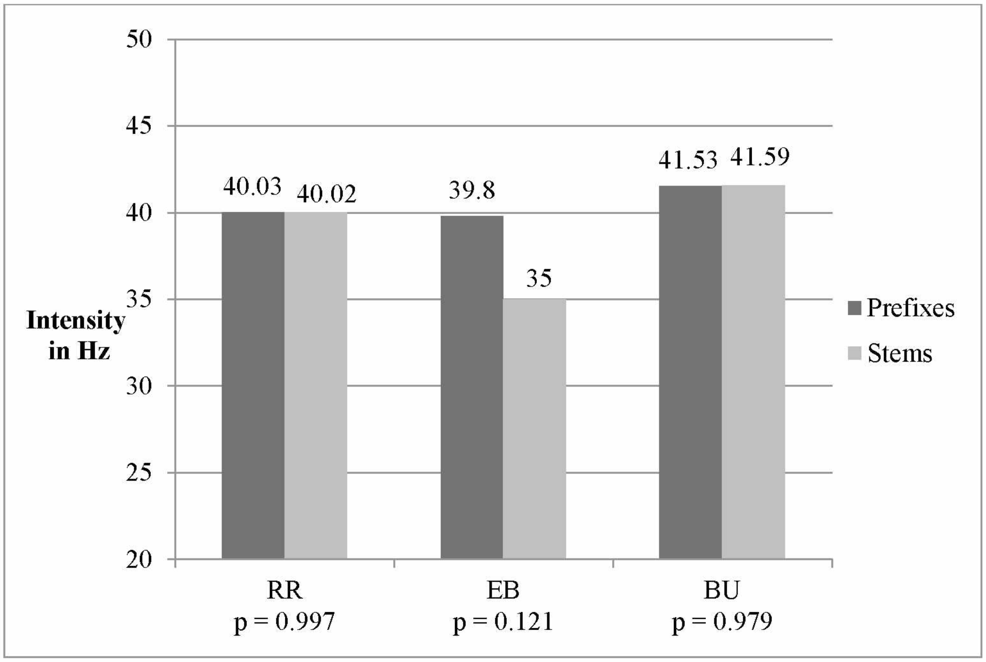


FIGURE 2.21: MEAN INTENSITY OF WORD MEDIAL /ð/ ACCORDING TO MORPHOLOGICAL ENVIRONMENT FOR DIFFERENT SPEAKERS

This data does not suggest any significant morphologically conditioned difference in fricative intensity. This is somewhat surprising since stem onset /ð/ tends to be more voiceless than in prefix onsets, and considering the fact that voiceless fricatives may have more high frequency intensity than their voiced counterparts (as was found in Holton 2000 and is also the case in the data of this study.).

2.4. Analysis and Discussion. In examining the duration, voicing, and high frequency intensity of Hän fricatives, some distinct differences have been found between their realization in stem versus prefix onsets. Duration is the most regular of these differences. Fricatives in prefixes were on average 56.2% the duration of fricatives in stems, and this ratio was found to be similar for each speaker (figure 2.3). In comparing each fricative phoneme, stem onset variants were also much longer than their prefix onset variants (figure 2.4). The realization of voicing was less clear. When comparing the word medial voiced fricative /ð/, those in prefixes were much more likely to be fully voiced than in stems (70% to 24.5%). The average total voicing in prefixes was 85.8% compared to 66.3% in stems. However, it cannot be said from this data that stem onset voiced fricatives are semi-voiced (partially or erratically voiced) and that prefixes are fully voiced, as some 30% of the prefix onset voiced fricatives were only semi-voiced. This study found no correlation between morphological environment and high frequency intensity. While voiceless fricatives had more frication than their voiced counterparts, stem fricatives did not seem to have any increase in intensity as opposed to prefix fricatives.

Therefore, it appears likely that the only fundamental phonetic distinction between stem and prefix onset fricatives is duration. While voicing is applied differently to stems and prefixes, it in fact displays some correlation to the length of the fricative, although this is not immediately clear. For example, if we look at stem onset word medial position (because we know initial position can have some effect on voicing), we find that for all examples there is a -0.14486 Pearson correlation coefficient between duration and total voicing percentage. This is not a strong correlation, and with 139 tokens, the p value is 0.088, which is not less than the usually accepted p value of 0.05 which would indicate significance. However, an analysis of each place of articulation shows a clear trend. All the sibilant voiced fricatives (/z/, /ž/, and /zr/, again in stem onset word medial position) displayed a strong *positive* correlation between duration and voicing, with a Pearson correlation coefficient of 0.6979 and a p value of 0.0002. That is to say, the longer a voiced sibilant, the more voiced it was, and vice versa. This correlation can be seen below in figure 2.22.

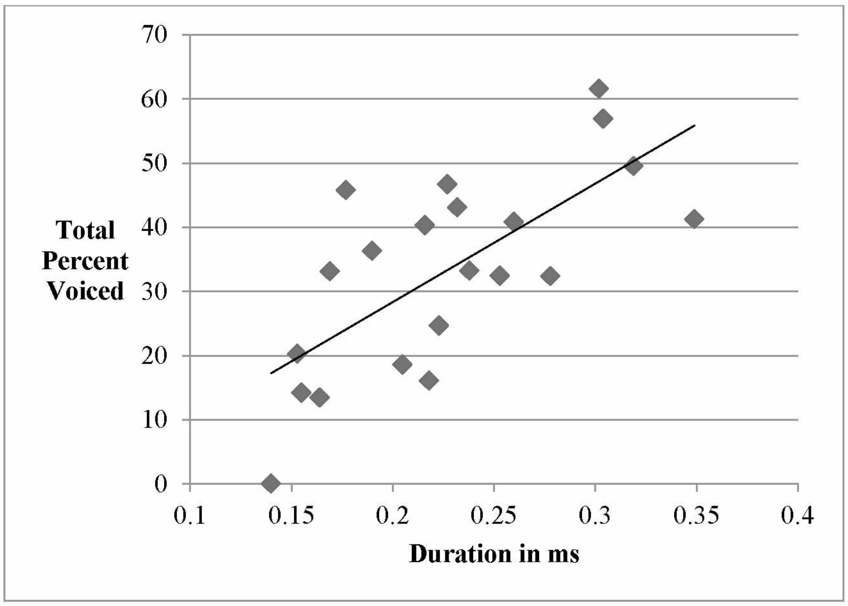


FIGURE 2.22: CORRELATION BETWEEN DURATION AND TOTAL VOICING PERCENTAGE FOR STEM ONSET WORD MEDIAL VOICED SIBILANTS (/z/, /ž/, /zr/)

The situation for non-sibilant stem onset word medial voiced fricatives (/ð/, /ɣ/, and /l/, realized as [ɮ]) was much more complicated. Unlike the sibilants, which were never completely voiced, the non-sibilant voiced fricatives were completely voiced in stem onsets in some cases. When these phonemes were completely voiced, they tended to be shorter. For example, word medial stem onset /ð/ tokens that were fully voiced averaged 160.3 ms compared to 220.2 ms for the tokens that were not completely voiced (p = 0.001). The one example of a stem onset word medial /ɣ/ that was completely voiced was only 153 ms in duration compared to an average of 254 ms for all tokens of /ɣ/ in this environment. The three examples of fully voiced /l/ (that is, [ɮ]) in word medial stem onset position averaged 188 ms compared to 214 ms for all tokens of /l/ in this environment. Fully voiced variants of prefix onset /ð/ in word medial position averaged 118.9 ms compared to 137.2 ms for semi-voiced variants (p = 0.14).

However, among the non-sibilant voiced fricative (/ð/ /ɣ/ /l/) tokens that were not fully voiced, correlations between duration and total voicing percentage were not so clear. These correlations for /ð/ and /ɣ/ were positive that for /l/ was negative, but none of these correlations was significant. The chart below in figure 2.23 shows both fully voiced and semi-voiced variants of /ð/ in word medial stem onset position.

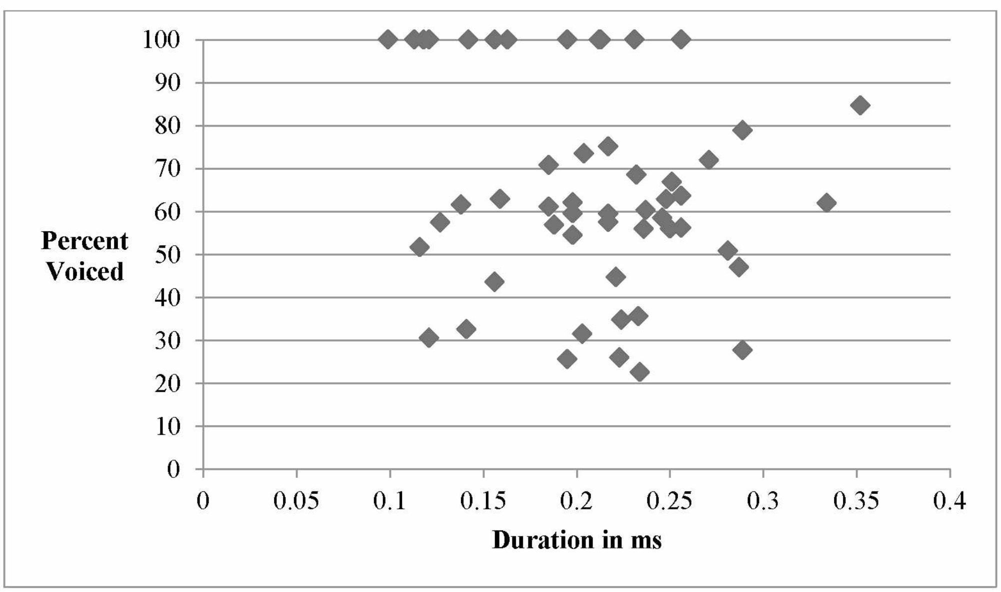


FIGURE 2.23 CORRELATION BETWEEN VOICING AND DURATION OF /ð/ IN WORD MEDIAL STEM ONSET POSITION

This chart shows once again that fully voiced (100%) variants of /ð/ in stems are indeed significantly shorter, but it is unclear how the semi-voiced variants are correlating.

Other factors which may influence the total voicing percentage of fricatives include the intensity of a given speaker or the emphasis given to a particular word, which might explain some of the weak or odd correlations. Such variables might be hard to operationalize, but various techniques of normalization to reduce the effect of speaker and intensity differences may help to provide clearer results in the future.

There is also a weak but very significant correlation between total voicing percentage and high frequency intensity. That is to say, voiced fricatives that were less voiced tended to have more energy in their higher frequencies (that is, stronger frication). The Pearson correlation coefficient was -0.210 for total voicing percentage and intensity, and with 249 examples (including stem and prefixes in both word initial and medial positions), the p value was 0.0004, which indicates a very good chance of at least a small amount of correlation. While Holton (2000:109) states that "semi-voiced fricatives do appear to contain less high-frequency noise than do their voiceless counterparts," the data from this study indicates that at least in Hän, this decrease is not a quality of semi-voiced fricatives (that is, phonemically voiced fricatives occurring most often in stem onset position), but is directly related to the fact that a semi-voiced fricative is more voiced than a voiceless fricative. This negative correlation between voicing and frication intensity may occur cross-linguistically but requires further study.

2.5. Conclusion. This study has identified and investigated several synchronic effects of fricatives in the Hän language that indicate stem prominence. The most regular of these effects is the increase in duration in stem onsets. Stem onset fricatives tend to be nearly twice the length of prefix onset fricatives. Additionally, stem onset fricatives also tend to be semi-voiceless, although this is found to correlate in complicated ways with duration. Fully voiced stem onset fricatives tend to be shorter, but in many cases the stem onset fricatives that were not fully voiced (semi-voiced) displayed a significant positive correlation with voicing, meaning that longer segments were more voiced (this was especially true for the sibilants). These semi-voiced variants of voiced fricatives were not found to pattern regularly as allophones according to morphological class (stem or prefix), although they were much more likely to occur in stem onsets where longer duration was in fact found to be regular. Additionally, this study finds that a decrease in high frequency intensity is a correlate of voicing, and is not an innate phonetic feature of fricatives in any particular morphological environment.

The longer duration of these segments is interpreted as being the result of stem prominence. This synchronic effect of longer stem onset fricatives, along with its correlating phenomena (such as semi-voicelessness), is considered to be a continuation of many diachronic processes that developed a fricative voicing distinction as a result of morphological conditioning. For example, weakening of segments, such as the voicing and lenition (fricatives becoming approximants) of certain more grammatical prefixes is a diachronic process that highlights how phonological processes are applied to reflect the historical morphological structure, and as a result can grant prominence to segments according to morphology. Thus, in the modern language, duration and its correlates indicate stem prominence in onset fricatives.

Chapter 3 Stops

This section investigates the realization of stops as they occur in stem and prefix onset position in the Hän language. Some impressionistic accounts (Hoijer 1945, Young & Morgan 1987) of Athabascan phonology have suggested that consonants in certain morphological environments may display longer durations than others, a feature related to the concept of prominence. Tuttle (2005) further investigates these observations in data from San Carlos Western Apache and finds a morphologically conditioned lengthening of stops in stem initial position. Given the results of §2 concerning fricatives, the question arises as to whether other obstruents or all other consonants might pattern similarly. If this is the case, stops would be expected to display different characteristics for denoting stem prominence from fricatives, given the fundamentally different acoustic properties of these sounds, such as the fact that stops are generally voiceless in Athabascan languages, unlike fricatives. This study investigates the synchronic, morphologically-conditioned effects of stem prominence as it occurs in stops (plosives, affricates, nasals, and ejectives) through comparison of closure and release durations, voice onset quality, and intensity.

3.1. Pulmonic Stops. Due to fundamental differences in acoustic properties of ejectives, as well as their treatment in previous literature, the first half of the chapter on stops will cover only the pulmonic stops, including the nasal, plain, and aspirated stops, while the second half will be devoted to ejectives.

3.1.1. Background and Literature Review.

3.1.1.1. Diachronic Obstruentization of Stem Initial /n/. Oral stops, being obstruents, are low on the sonority hierarchy, and as a result these sounds cannot undergo any phonemic fortition. Additionally, oral stops in Hän never weakened in prefix onset position, as did some fricatives (§2.1.1.), either by becoming voiced or displaying lenition with respect to manner of articulation. However, the nasal stop /n/, historically a sonorant, obstruentized in a specific, morphologically conditioned environment. When in stem initial position, in the absence of other nasal segments within the stem syllable, including nasalized vowels, original /n/ became /^{n}d/, a prenasalized stop (Ritter 1979). Table 3.1 below shows examples of where this change occurred and where it did not:

TABLE 3.1: HÄN NASAL OBSTRUENTIZATION

Pre-Hän	Early Hän
***nun 'game animal'**	/nun/
***nan 'land'**	/nan/
***nu 'island'**	/^{n}du/
***dəne 'man'**	/də^{n}de/

In modern Hän, /^{n}d/ has continued strengthening, becoming a true voiced stop /d/, and has palatalized to /ǰ/ before /i e æ u ə/ in the Eagle dialect (Ritter 1979). This is somewhat similar to the development of Proto-Athabascan sonorant /w/ which became a full voiced /b/ in stem initial position (as mentioned in §2.1.1.4., patterning also like the fricatives). Fully voiced /d/ (along with palatalized /ǰ/), has merged with its voiceless unaspirated counterpart for some speakers (and likewise /b/ has also become voiceless and unaspirated for these same speakers but there was no voiceless /b/ to merge with).

3.1.1.2. Consonant Lengthening in Southern Athabascan. A few sources in particular have described consonants in certain phonological environments as being longer in duration or "doubled" (Young and Morgan 1987:xv) in Southern Athabascan languages such as Navajo. Hoijer's (1945) description of Navajo phonology states that "when an initial or medial Cv [syllable] precedes another syllable that begins with a consonant, the consonant of the second syllable is mechanically lengthened" (3). Given this description and the examples, Hoijer's interpretation seems to be that the process occurs as a result of the phonological environment, and no attention is given to the morphological environment. Young and Morgan (1987) provides a similar description, with emphasis on the phonological environment but a disregard for possible morphological influence. In the introduction on Navajo phonology it asserts that "consonants tend to be doubled when they occur intervocalically--- that is, the consonant that begins a syllable tends to also close a preceding open syllable" (xv). The fact that this gemination occurs on a clear prefix-stem morpheme boundary in a majority of the examples is left unmentioned. Additionally, in three syllable examples where a prefix has been attached to a disyllabic stem, this gemination is only transcribed as being on the prefix-stem boundary, such as in *bit-tsilí* 'his younger brother' as opposed to *bit-tsil-lí* or *bi-tsil-lí*. This would indicate that this is not simply a process of consonants doubling "intervocalically" but rather, a process occurring at the beginning of stems.

Tuttle (2005) provides a quantitative inquiry into this matter based on data from the San Carlos dialect of the Western Apache language. Her study also differs from previous descriptions in considering the possibility that these intervocalic stops may be lengthened as the result of morphological conditioning, rather than phonological conditioning or as a means of closing a preceding open syllable. Examples of /n/ as well as the plain stops /d/ and /b/ (phonetically unaspirated [t] and [p]) were measured in medial position for closure duration, and for /d/ and /b/, voice onset time. The closure duration for /d/ and /b/ was found to be nearly twice as long in stem onset position while there was no significant difference in voice onset time according to morphological environment. The phoneme /n/ in prefixes was also measured at about two-thirds the length of that in stems, 87 milliseconds compared to 124 milliseconds. The amplitude of /n/ was also measured, but there was no significant morphologically conditioned effect.

Additionally, Bird (2004) examined the length of intervocalic consonants, finding them to be longer in the Lheidli Carrier language. Hargus (2010), however, finds that consonants are no longer in intervocalic position than in initial position, comparing the durations of fricatives (which are easier to measure in initial position than stops due to stop closures consisting of only silence). Her results show that stress is a more important factor in consonant length, although she does not distinguish between stem prominence (the focus of this study) and stress.

3.1.2. Methodology. This study analyzed recordings of 116 examples of pulmonic stops produced by a single fluent speaker of Hän. This speaker, RR, is female and was raised in Eagle, Alaska. All tokens were recorded with a Zoom H4n Handy Recorder using its internal microphone at a sampling rate of 44.1 KHz and a bit depth of 16 bits. Examples were analyzed using Praat version 5.2.13 (Boersma & Weenink 2009). A two-tailed t-test was applied to the data when needed to analyze variance. A p-value of .05 or lower was considered to indicate significance.

The targeted words included examples of the stops /d/, /t/,/ǰ/, /č/, and /n/ in both stem and prefix onset position. These phonemes were selected due to their high frequency in both stem and prefix onsets--- some stops and affricates may not ever occur in prefix onsets in Hän. All tokens were located in word medial position, due to the fact that, unlike fricatives, stop closure duration would be difficult to measure in initial position, being that closure is usually denoted by silence (measurements for /n/, being a sonorant, would be possible but this environment was avoided for consistency). For the obstruents, the duration of the release was also measured. Voice onset time was measured for /d/and /t/ while length of frication was measured for the affricates /ǰ/ and /č/. Frication for /ǰ/ and /č/ was interpreted as beginning at the point of high frequency energy and ending with the onset of the following vowel. This may include voice onset time as well in the case of affricates, but it was too difficult to separate the two values. Intensity of the releases--- either aspiration or frication--- was also measured and compared.

3.1.3. Results.

3.1.3.1. Nasals (/n/).

3.1.3.1.1. Nasal Closure Duration. Nasals, having no release separate from a closure, had only a single measurement of duration. In Hän only the nasal /n/ occurs in both stem and prefix onsets. The phoneme /m/ occurs allophonically as [w] in prefixes and /ŋ/ occurs only in stem final position (or as an allophone of /n/ before velar obstruents). Nasals in stems were determined to be slightly longer in stem onsets than in prefix onsets, as shown below in figure 3.1.

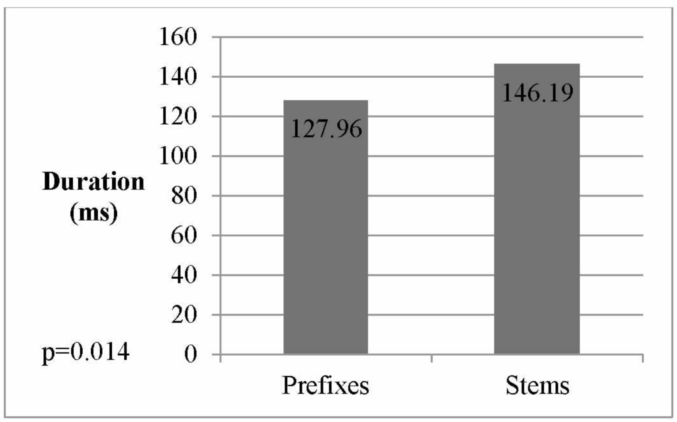


FIGURE 3.1: COMPARISON OF /n/ CLOSURE DURATION ACCORDING TO MORPHOLOGICAL CATEGORY

3.1.3.1.2. Nasal Intensity. The difference in intensity between prefix and stem onset nasals was found to be insignificant. Prefix onset /n/ averaged 66.75 dB while stems average 68.07 dB, but with a p-value of 0.162.

3.1.3.2. Plosives (Non-Affricates, /d/ and /t/). The phonemes /d/ and /t/, which are a voiceless unaspirated (plain) alveolar stop [t] and a voiceless aspirated alveolar stop

[t^h] respectively, both contain a period of closure, consisting more or less of silence, and a release, measured in terms of voice onset time. The phoneme /t/ is heavily aspirated in Hän, while /d/ is unaspirated and thus has a very small voice onset time which is usually very close to 0 milliseconds (but is never negative). Despite following this same acoustic format of closure plus release, the two phonemes follow a different pattern in displaying stem duration increase.

3.1.3.2.1. Plosive Closure Duration. For the phoneme /d/, stop closure was found to be significantly longer in stem onset position than in prefix onset position, with an average of 218.83 ms stems and 166.22 ms for prefixes (p = 0.004). However, there was no significant difference in closure length for /t/. The average closure duration was actually higher for prefixes, 176.46 ms as opposed to 148.16 ms for stems, but with a p value of 0.167.

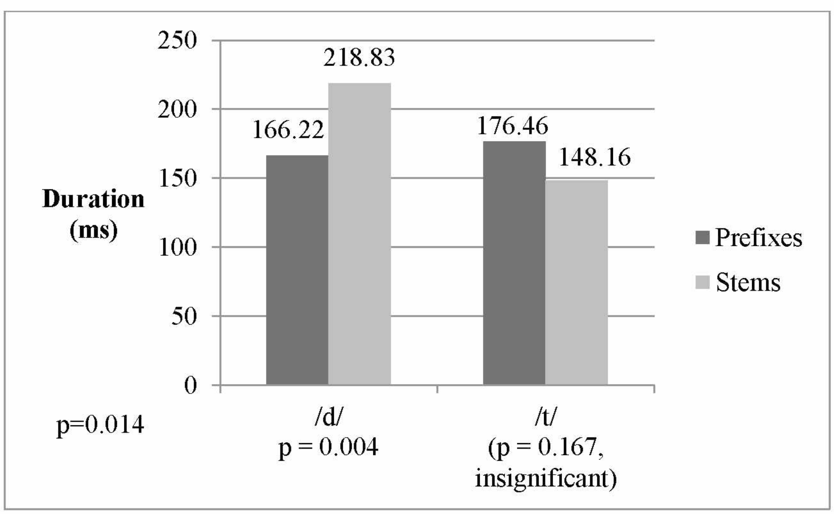


FIGURE 3.2: COMPARISON OF /d/ AND /t/ CLOSURE DURATION ACCORDING TO MORPHOLOGICAL CATEGORY

3.1.3.2.2. Plosive Voice Onset Time. For both /t/ and /d/, the voice onset time was measured, taken from the beginning of the plosive release to the beginning of the following vowel. Because /t/ is heavily aspirated in Hän (that is, [t^h]), it is no surprise that its voice onset time is much higher in both stems and prefixes than that of /d/ (phonetically unaspirated [t]). What is perhaps surprising is the fact that /t/ displayed morphologically conditioned voice onset lengthening while /d/ did not, the opposite scenario which occurred in comparing closure duration. Thus, /t/ in prefixes has a voice onset time of 106.6 ms and 152.7 ms in stem ($p = 0.003$). The phoneme /d/, on the contrary, has a VOT of 13.57 ms in prefixes and 13.38 ms in stems, with a p value or 0.918, far from significant. What is particularly interesting here is the fact that both /d/ and /t/ are longer in stem onsets, but this increase in duration is manifested in different ways: /d/ has a longer closure, while /t/ has a longer VOT.

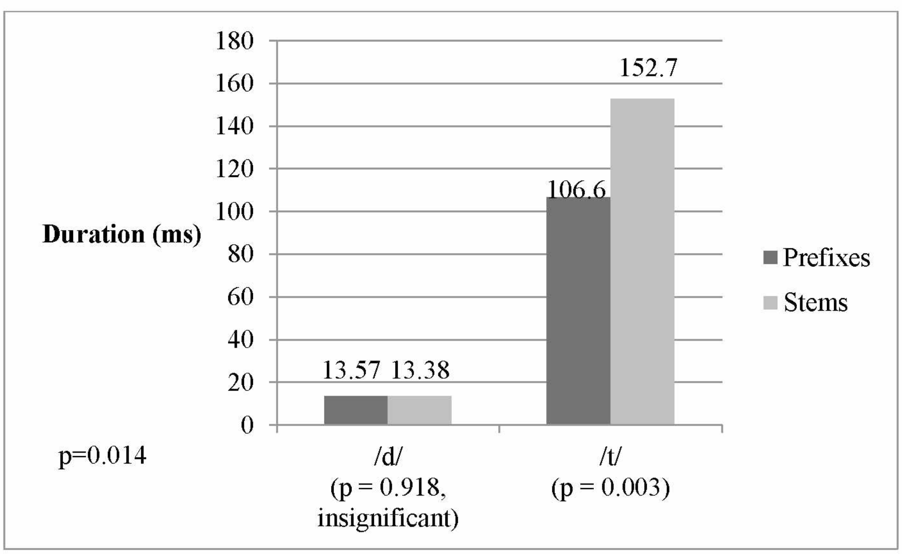


FIGURE 3.3: COMPARISON OF /d/ AND /t/ VOT ACCORDING TO MORPHOLOGICAL CATEGORY

3.1.3.2.3. Plosive Intensity. As with /n/, no significant increase in intensity was found in stem onsets for either phoneme. For plosives, the intensity of the release was measured, which included the aspiration of /t/. The release of /d/ averaged 62.18 dB in prefixes and 62.16 in stems, with a p value of 0.989; the release and aspiration of /t/ averaged 55.41 in prefixes and 56.24 in stems with a p value of 0.56. Either p value is far too high to render any difference here meaningful.

3.1.3.3. Affricates (/č/ and /ǰ/). Closures for affricates are quite similar to those of non-affricates, that is, a complete obstruction of the airflow, characteristic of all stops. However, affricates are more complex sounds than their non-affricate counterparts, having a fricative release in addition to any aspiration that may occur before the onset of the following vowel.

3.1.3.3.1. Affricate Closure Duration. There was no significant difference in the closure duration of /č/ or /ǰ/ in stems or prefixes. The closure of /č/ averaged 139.64 ms in prefixes and 135.05 ms in stems with a p value of 0.705. The closure of /ǰ/ averaged 148.00 ms in prefixes and 142.74 ms in stems, with a p value of 0.640.

3.1.3.3.2. Affricate Release Duration. For the purposes of this study, both frication and any possible aspiration were considered part of the release. The phoneme /č/ is considered aspirated, phonetically [$\check{c}^h$], while /ǰ/ is a plain, voiceless, unaspirated affricate [č]. Visually it was difficult to separate aspiration and frication in the spectrogram, but /č/ was clearly differentiated from /ǰ/ by having a longer frication period measured from the moment of release to the onset of the following vowel (The total frication period of /č/ averaged 159.16 ms in all morphological environments while /ǰ/'s frication period averaged 116.00 ms in all environments, $p < 0.001$). The phoneme /ǰ/ definitely displayed a significantly longer release in stems than in prefixes, while the difference between the release of /č/ in stems and prefixes was questionable. The release of /ǰ/ in prefixes averaged 107.6 ms compared to 129.59 ms in stems, with a p value of 0.034. The release of /č/ in prefixes averaged 145.68 ms compared to 168.15 ms in stems, but with a p value of 0.082, a bit higher than the 0.05 cut-off for significance, though we might say trending significance. However, removing a single outlier, a stem onset example /wəčæ̀ʔ/, <wëchà’>, ‘his father,’ yielded a p value of 0.02. In this example, and others like it, the durations (both the closure and total release) were much shorter, perhaps because phonetically the onset contained a consonant cluster, with the word being pronounced as [wčæ̀ʔ]. This was even more true in the case of /ščæ̀ʔ/ where the word was reduced to undeniably a single syllable, and the duration of the release of /č/ tended to be about 50 -75 milliseconds. This was not the case in an example such as /ǰi wəčèʔ/ where the reduced prefix /wə/ could be attached to the previous syllable, thus yielding [ǰiw.čèʔ] and a longer release for /č/. However more study of this observation is needed before removing such environment from the data.

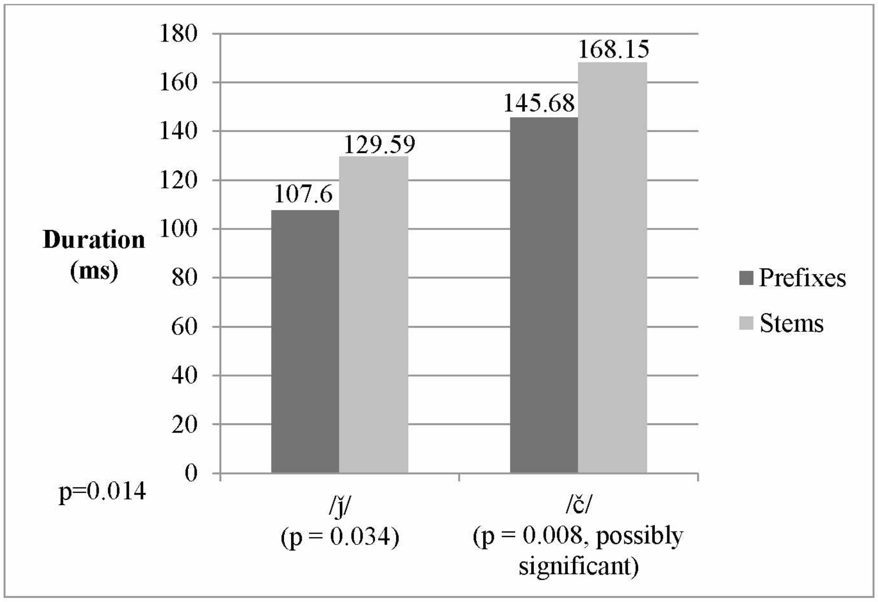


FIGURE 3.4: COMPARISON OF /ǰ/ AND /č/ TOTAL RELEASE DURATION ACCORDING TO MORPHOLOGICAL CATEGORY

3.1.3.3.3. Affricate Intensity. The phoneme /č/ joins the non-affricate stops /n d t/ in not displaying a significant difference in release intensity between stems and prefixes. The release intensity /č/ averaged 66.50 dB in prefixes and 65.85 dB in stems with a p-value of 0.609. However, the release intensity of /ǰ/ in stems, 62.56 dB, was in fact higher than that in prefixes, 65.6 dB, with a p-value of 0.002.

3.1.4. Analysis and Discussion.

3.1.4.1. Duration. More or less all phonemes, save perhaps /č/, displayed a significant increase in duration in stems as opposed to prefixes. However, this durational increase was achieved in quite different ways. The phoneme /n/ is fundamentally different from the oral stops, lacking a distinction between closure and release, and thus its increase was realized in this single parameter. Of the four oral stops, /d/, /t/, /ǰ/ and /č/, only /d/ displayed any morphological conditioning of closure duration, while lacking any difference in release time according to morphological environment. On the other hand, the closure duration /t/, / ǰ/, and /č/ in stems was not significantly different from prefixes, but the releases were longer, whether manifested as aspiration (/t/), frication (/ǰ/) or both /č/. This makes some sense due to the fact that the VOT of /d/ is so short and any increase in VOT could cause this sound to become acoustically too similar to /t/.

3.1.4.2. Intensity. For most phonemes, there was no significant morphologically conditioned difference in stop onset intensity. However, /ǰ/ did show an increase in release intensity in stems. It is unclear if for some reason this is the only stop with a significant morphologically conditioned difference in release intensity, or if all stops have a slight increase in intensity that was too small to achieve significantly different averages in a data set of this size. Even when comparing all data however, there was no significant difference, with an average release intensity of 63.4 dB in prefixes and 64.2 dB in stems, but with a p-value of 0.365. Future inquiry of this question may also be more accurate if intensity values are normalized to lessen the effects of individual word volume differences.

3.1.4.3. Comparison with Previous Literature. Ostensibly, this study seems to agree with the findings of Tuttle (2005) and the general descriptions of consonant lengthening, particularly in Young and Morgan (1987). However, although more or less all phonemes were realized with longer duration of some sort in stems, this increase was nowhere near what we would expect from the “doubling” described impressionistically in Young and Morgan (1987) or even the quantitative results obtained from Tuttle (2005). Figure 3.5 shows prefix-to-stem ratios of the significantly different features of each phoneme according to morphological category from Hän, next to the findings of Tuttle in San Carlos Western Apache (2005).

This data, though it may require further study, seems to indicate that the prefix and stem onset duration difference is more pronounced in San Carlos Western Apache than it is in Hän. Besides some instances of /d/, the duration increase in Hän stem onset stops is not readily apparent, according to the researcher’s perception (especially when compared to the difference in fricative duration, in which stem fricatives are almost double the length, see §2). This data is more similar to that of Hargus (2010), where fricatives in unstressed syllables were found to range between about 63% and 82% of the length of fricatives in stressed syllables for different speakers (of course this data did not distinguish between word and morphological stressed, and examined fricatives instead of stops). Furthermore, Müller (2009) states that according to her own impressions of Beaver, that the lengthening of intervocalic segments is not as pronounced as in Carrier, indicating variation within Athabascan languages. Thus, this duration increase in Hän, and possibly some other Northern Athabascan languages, may be a physical reflex indicating the underlying morphological structure at a more subconscious level, as opposed to a regular, perceptible feature of Hän phonology.

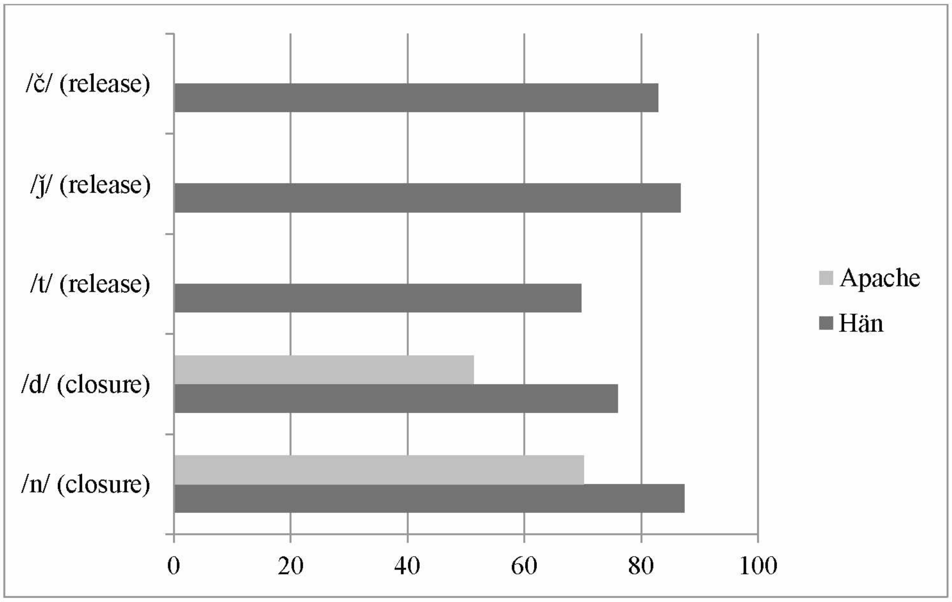


FIGURE 3.5: AVERAGE STOP PREFIX ONSET DURATION AS A PERCENTAGE OF THE AVERAGE STOP STEM ONSET DURATION (WITH COMPARISON TO S.C. WESTERN APACHE (TUTTLE 2005))

3.2. Ejectives. In some ways ejectives are acoustically similar to the pulmonic stops, particularly in that they have a closure period of silence followed by a release before the onset of the following vowel, although with this being accomplished through manipulation of the glottalic airstream mechanism. However, because of this difference in laryngeal setting, a variety of voicing effects can occur during the transition from the glottalic to pulmonic airstream. While measuring the closure is no problem, defining the boundaries of the release is difficult because often the following vowel begins with tense or creaky voice, influenced by the preceding ejective.

3.2.1. Background and Literature Review. Most of the previous literature concerning ejectives has attempted to understand their acoustic properties and the variation they display. While duration has been measured with several environments considered, previous studies have not focused solely on the effects that the morphological environment might have.

3.2.1.1. Cross-Linguistic Descriptions of Ejectives. Kingston (2005) suggests that the realization of ejectives varies in the languages that have them. He described two basic types of ejectives: stiff and slack (or strong and weak). So-called stiff ejectives are produced with a tightly closed glottis, a strong release in the form of a burst, and a delay before the voice onset of the following vowel. The voice quality following the release begins either modal or tense with a higher F0. Ejectives such as these have been observed in Salish, Tigrinya, Tsez, Tlingit, and the Athabascan languages Navajo, Western Apache, Chipewyan, and Hupa. Contrastively, slack ejectives have a less tightly contracted closure with a less intense burst which is no more intense than that of a pulmonic stop; voicing begins shortly after the release, and is creaky in quality with a lowered F0. Such ejectives have been described in Quiché, Hausa, Hadza, and the Athabascan languages Witsuwit'en, and Minto (Lower Tanana) and Dakelh in certain instances (Kingston 152).

TABLE 3.2: STRONG VS. WEAK EJECTIVES, FROM HAM (2008)

	Strong / Stiff Ejectives	Weak / Slack Ejectives
VOT	long	short
Voice Quality	modal or tense	creaky
Pitch at Voicing Onset	raised	lowered
Amplitude at Voicing Onset	sudden increase	gradual increase
Ease of Perception	easy	hard

3.2.1.2. Descriptions of Ejective Variation in Athabascan. A number of studies have observed a wide amount of variation in ejective production in Athabascan languages, with a variety of analyses for this variation. Tuttle (1998) describes the Minto dialect of Tanana Athabascan as having both strong and weak ejectives, as well as noting a duration increase in stems. Bird (2002) finds that in Dakelh (Carrier) speakers may use either type of ejective, but that /t'/ and /k'/ tend to be weak while /č'/ and /ts'/ tend towards the stronger variant. Wright et. al (2002) states that for some speakers of Witsuwit'en, the ejective and plain (unaspirated) series were difficult to distinguish, perhaps implying the existence of a slack-like ejective. Expanding on this study, Hargus (2007) rejects Kingston's dualistic ejective typology, while noting variation in ejective production in Witsuwit'en. Her data shows that there is no significant correlation between voice onset time and any lowering or raising of F0; that is to say, there was no clear divide between ejectives with long releases and raised pitch at the beginning of the following vowel and those with short releases and lowered vowel onset pitches. Instead, she adopts the view that slack and stiff ejectives represent "two extreme types, or two ends of a continuum" (96). McDonough and Wood (2008) also finds a great deal of variation in ejective duration in Dene Sųłine, Dogrib, North Slavey, and Tsilhqut'in.

3.2.2. Methodology. This study investigated the acoustic properties of 63 ejective tokens, covering four phonemes, /t'/, /k'/, /č'/, and /tr'/. All examples were spoken by a single fluent speaker of Hän, RR, originally from Eagle, Alaska. These were obtained using a Zoom H4n Handy Recorder with internal microphone at a sampling rate of 44.1. KHz and a bit depth of 16 bits, and were analyzed using Praat version 5.2.13 (Boersma & Weenink 2009). A two-tailed t-test was applied to the data when needed to analyze variance. A p-value of .05 or lower was considered to indicate significance. Examples of ejectives were compared in stem onset versus prefix onset position to consider their morphological conditioning.

3.2.2.1. Duration of Closure and Release. Duration of the closure in ejectives is more or less the same as in non-ejective stops, defined by the period of silence between the preceding segment and the burst of the stop's release. These examples were extracted from complete words in complete sentences in medial position, so the duration of the closure was clearly defined. On the contrary, the release of the ejective could be quite complex. As the results will show, often the releases were well-defined, extending from the burst of the ejective, enduring a gap, and ending upon the voice onset of the following vowel. However, some ejectives were less clearly defined, more like the "slack" or "weak" ejectives as defined by Kingston (2005). In these, there was often no perceivable gap following the burst, and there was a transitional voicing period where the voice quality began laryngealized (either creaky or tense) and gradually became modal. As a result, the length of the release was measured separately from the length of the laryngealization, when applicable. Length of laryngealization was defined as extending from the beginning of voicing, often defined by a formant around 500-900 Hz, to the point at which a lower frequency fundamental emerged and formants became darker (higher energy) and more clearly defined, as seen below in figure 3.6. It was therefore somewhat unclear whether the laryngealized portion was part of the ejective or vowel segment, given the features were mixed.

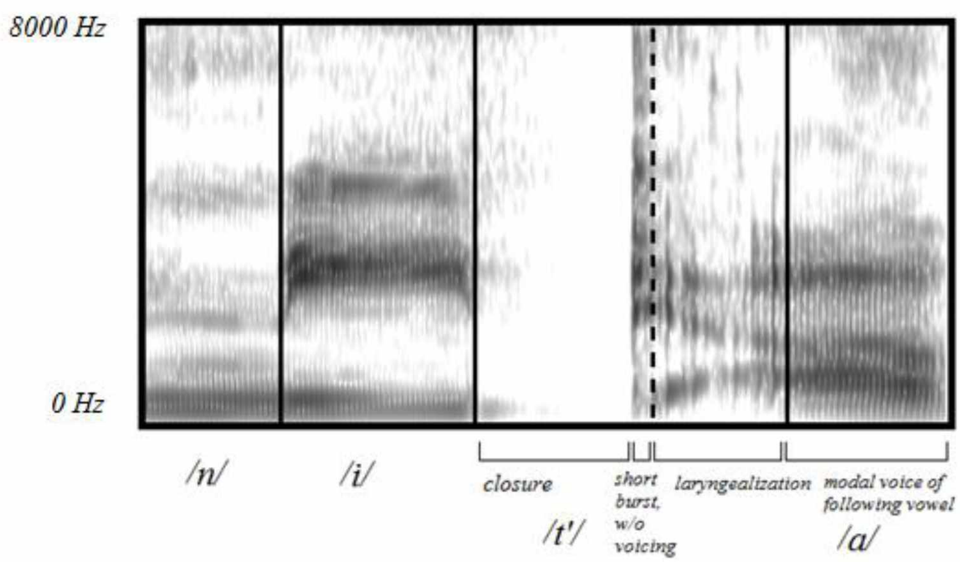


FIGURE 3.6: EJECTIVE WITH LARYNGEALIZED RELEASE:

First syllables of /nit'àðəžæ/ 's/he caught up with us.'

3.2.2.2. Voicing Effects and Rise Time. Following Wright et. al (2002) and Hargus (2007), this study also measured rise time as a means of quantifying the variation observed in ejectives. Rise time is defined as the difference between vowel intensity 30 ms after voice onset and at the vowel's peak. It is expected, due to the more gradual transition from creaky or tense voice to modal voice, such as in seen in 3.6, that such ejectives will display a higher rise time. Hargus (2007) also suggests various measurements of jitter in determining creak or laryngealization differences among ejectives. Jitter is the degree of irregularity of the voicing pulses, and has been found to be higher in creaky voice as opposed to modal voice (Ladefoged & Epstein 2001). However, in many examples like 3.6, Praat failed to place voicing bars in areas of heavy laryngealization, and such measurements were not possible. Some methods have been suggested for resolving this issue (Hargus p.c., Holton p.c.) but these were not utilized in this study.

3.2.3. Results.

3.2.3.1. Closure Duration. Closure duration was found to be significantly different for all four ejective phonemes, /t' k' č' tr'/ in prefixes as opposed to stems; this is different from the findings of §3.1.3., where closure duration was only significantly different in phonemes without much of a release (/n/ and /d/). A few outliers did have to be removed from the /t'/ data. All examples where /t'/ followed a nasal caused the ejective to much shorter, even in stems, which is similar to the findings of §3.1.3.3.2, where a preceding voiced consonant segment caused a decrease in duration. Interesting effects of this are also considered in §3.2.4. Figure 3.7 below shows the results for ejective closure duration.

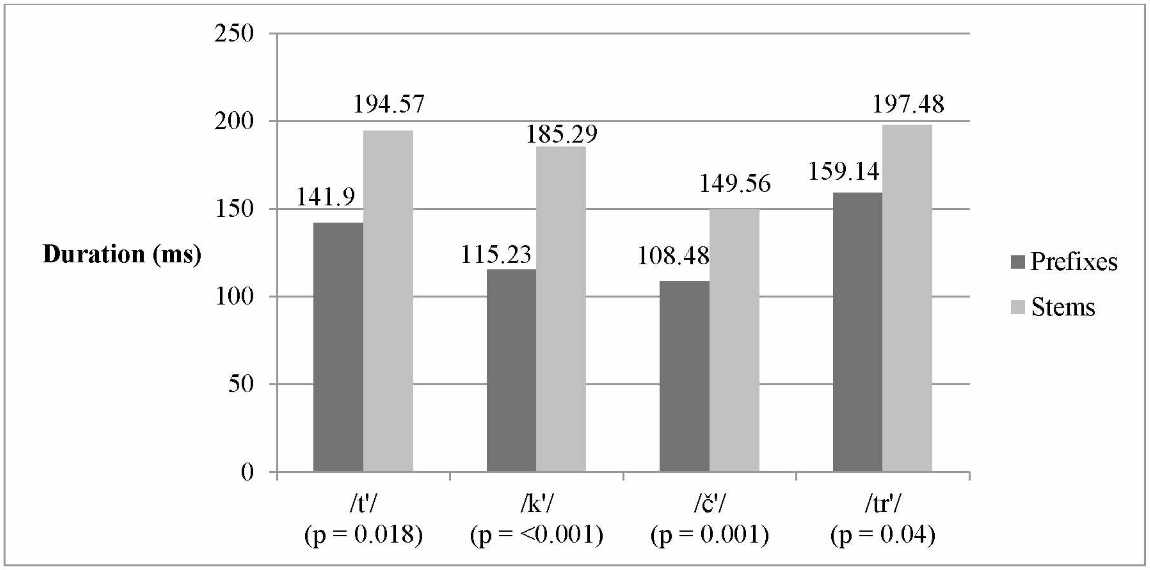


FIGURE 3.7: COMPARISON OF EJECTIVE CLOSURE DURATION ACCORDING TO MORPHOLOGICAL CATEGORY

3.2.3.2. Voice Onset Time. Voice onset time was defined as beginning with the ejective burst and ending with the onset of voicing of any quality, whether it be creaky, tense, or modal. The ejectives /t'/ and /k'/ were especially contrastive in duration in prefixes versus stems, as they generally exhibited laryngealization shortly after the burst in prefixes (more on this topic can be found in §3.2.3.3.). The ejectives /č/ and /tr'/ were less significant in their release duration difference according to morphological environment, and they were more likely to display a modal vowel onset even in prefix onset position (particularly /č'/). Figure 3.8 below demonstrates this contrast between the stops ejectives and the affricate ejectives.

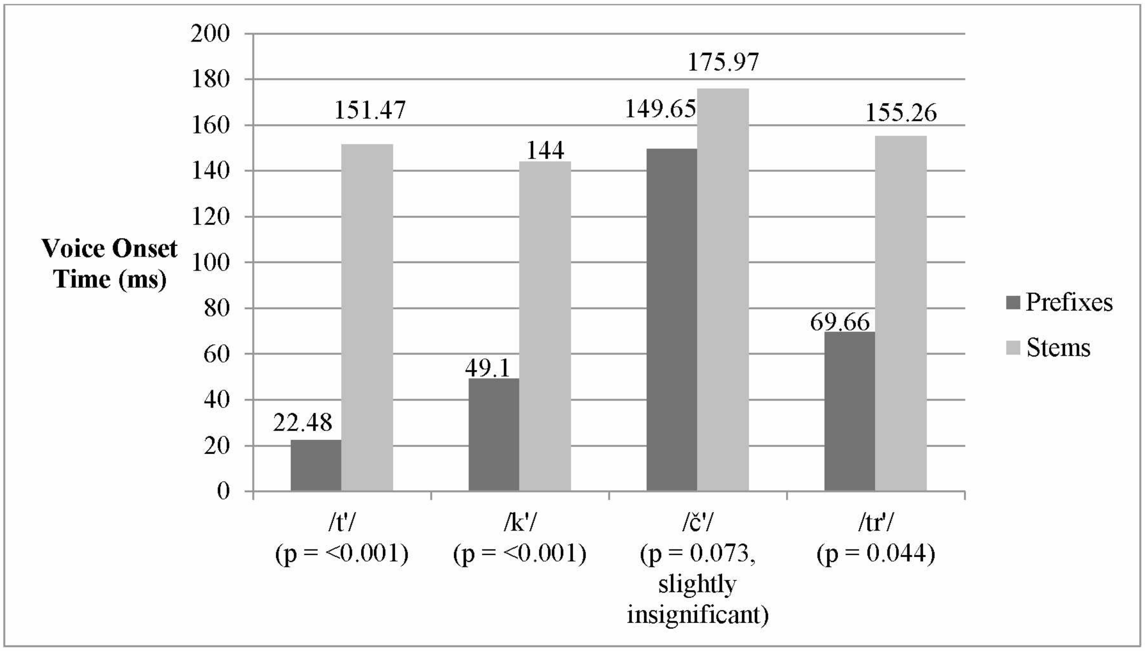


FIGURE 3.8: COMPARISON OF EJECTIVE RELEASE DURATION ACCORDING TO MORPHOLOGICAL CATEGORY

3.2.3.3. Voice Quality. In addition to release duration differences, another prominent way in which ejectives displayed variation was in the voice quality at the onset of the vowel. In prefix onsets, /t’/ and /k’/ in particular, and to a lesser extent /tr’/, VOT was very short, with no or little noticeable gap between the ejective burst and the voice onset. The primary distinction between these ejective allophones and the plain stops (unaspirated, voiceless) is that the vowel begins with a period of laryngealization, perhaps creaky, tense, or stiff voice. An example of this shorter, laryngealized ejective is seen in figure 3.9, with a longer example in 3.10. The methods used for measuring this are described in §3.2.2.

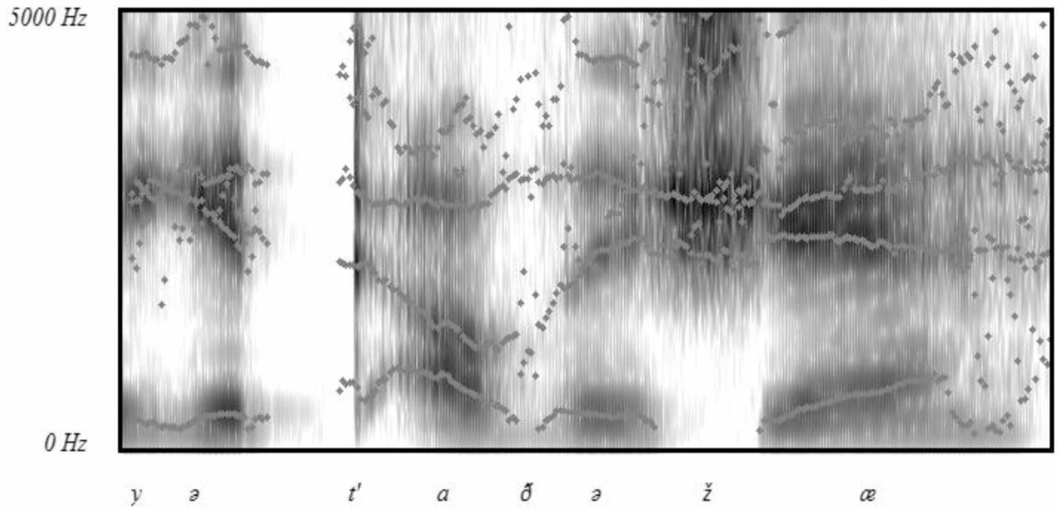


FIGURE 3.9: WEAK TYPE EJECTIVE /t'/ IN PREFIX ONSET: *No gap between burst and laryngealized vowel onset, /yət'àðəžæ/, 'he caught up with her'.*

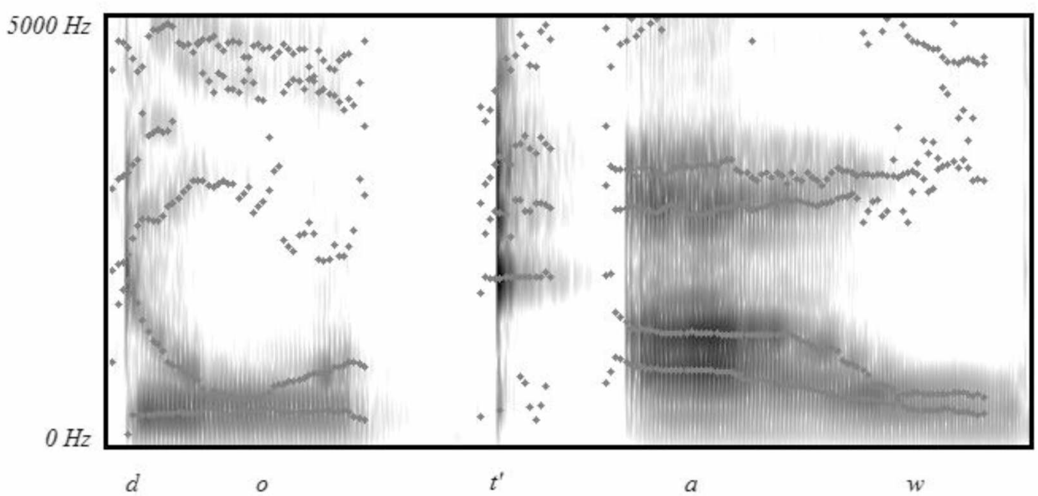


FIGURE 3.10: STRONG TYPE EJECTIVE /t'/ IN STEM ONSET: *Gap between burst and modal vowel onset, /dot'aw/ 'it is red'*

3.2.3.3.1. Occurrence and Frequency of Vowel Laryngealization. The table below (3.3) shows the percentage of tokens for each ejective at each place of articulation determined to be followed by a vowel with a significant amount of laryngealization (10 ms or more).

TABLE 3.3: PERCENTAGE OF EJECTIVE TOKENS FOLLOWED BY SIGNIFICANT VOWEL LARYNGEALIZATION

	Prefixes	**Stems**
/t’/	100%	0%
/k’/	100%	0%
/č’/	33.33%	8.33%
/tr’/	50%	33.33%

3.2.3.3.2. Ratio of Laryngealization Duration to Release Duration. This chart below in figure 3.11 shows the difference in post-ejective laryngealization duration whenever it occurs in different phonemes. A proportion was used in order to minimize the morphologically conditioned effects of duration lengthening among stems for better comparison. This is merely meant to demonstrate differences in the realization of the laryngealization across different phonemes and thus was not compared according to morphological category (when laryngealization did occur in stems, for example, its proportional length to the entire segment was not much different from that in prefixes). The release is defined as the period of voicelessness following the burst to the onset of laryngealized voicing. Thus, we see that the non-affricate ejectives /t'/ and /k'/ tend to have a much longer proportional period of laryngealization compared to their release.

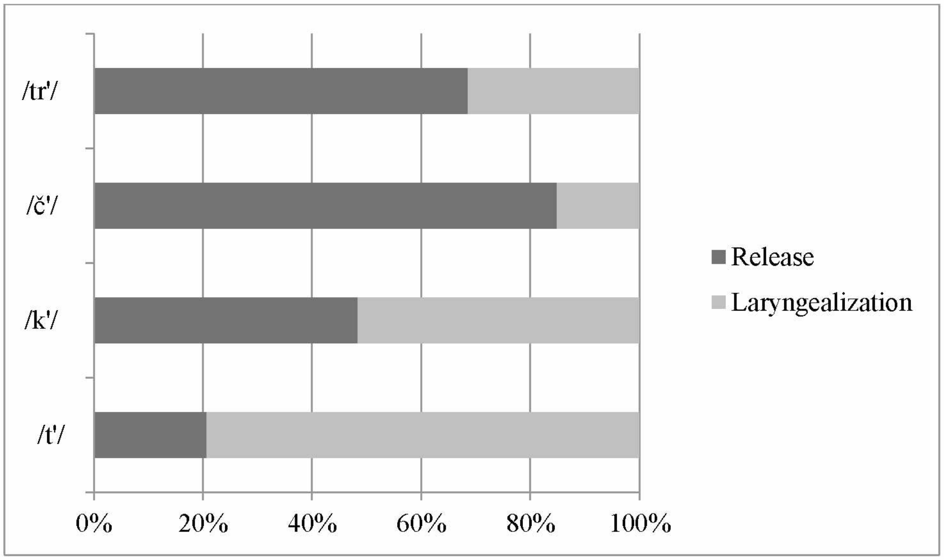


FIGURE 3.11: COMPARISON OF VOT TO LARYNGEALIZATION PROPORTION FOR DIFFERENT EJECTIVE PHONEMES

3.2.3.3.3. Rise Time. Rise time proved to be an additional useful measurement for indicating laryngealization patterns following ejective releases. Rise time, as was described in §3.2.2., measures how quickly a vowel reaches its peak in intensity. Voicing following "strong" ejectives such as that in figure 3.10 has a low rise time since the vowel has nearly reached its peak after 30 ms. Voicing following weaker-type ejectives such as that in figure 3.9 displays a gradual opening of the glottis as its voice changes from laryngealized to modal. Thus, this voicing is expected to have a higher rise time. Rise time for each ejective for each morphological environment is shown below in figure 3.12. It comes as no surprise then that rise time differences are not significantly different for /č'/ and /tr'/, since these were much less likely to display laryngealization following their releases in prefixes.

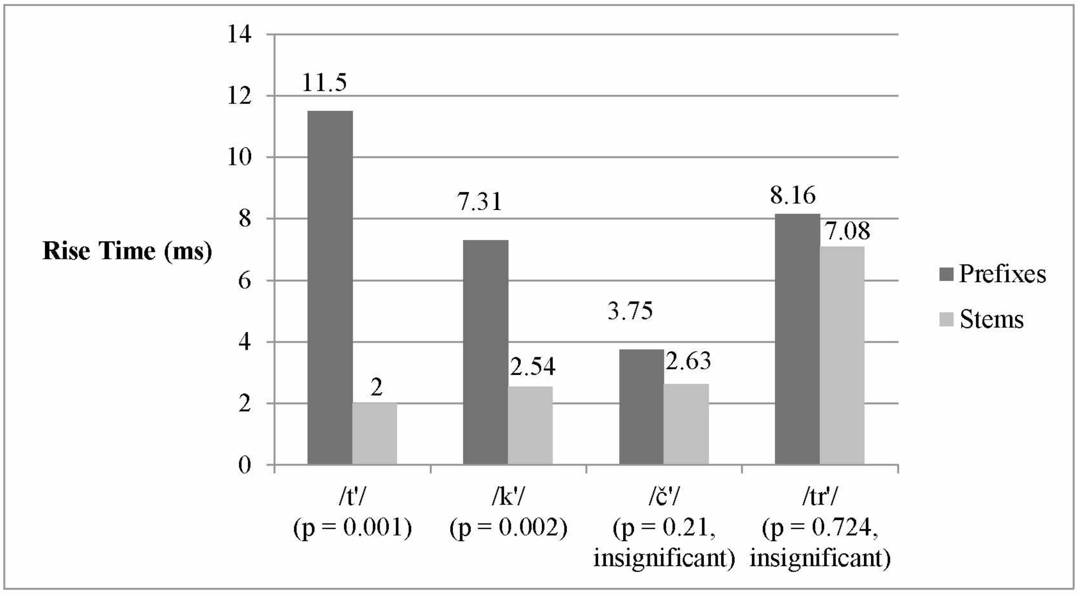


FIGURE 3.12: COMPARISON OF RISE TIME ACCORDING TO MORPHOLOGICAL ENVIRONMENT FOR ALL EJECTIVES

3.2.4. Analysis and Discussion. In agreement with Tuttle (1998), this study finds strong evidence of morphological conditioning of ejective duration. For all fricatives, closure duration is significantly shorter in prefixes as opposed to stems (see figure 3.7). Voice onset time of stems and prefixes harshly contrasted for the phonemes /t'/ and /k'/, and was somewhat significantly different for /č'/ and /tr'/ (see figure 3.8). /t'/ and /k'/ also displayed a longer laryngealization period than /č'/ and /tr'/ relative to voice onset timing, when laryngealization did occur (see figure 3.11). Differences in rise time between stems and prefixes was also particularly contrastive for /t'/ and /k'/, indicating a high rate of laryngealization upon voice onset in prefix /t'/ and /k'/.

This study indeed finds two types of ejectives that, at least in the features studied here, follow the models described in Kingston (2005). "Strong" or "stiff" ejectives are much like that in figure 3.10, with a long VOT preceding a well-defined modally-voiced vowel, and "weak" or "slack" type such as figure 3.9, with a short VOT and a laryngealized onset, gradually becoming modal. For /t'/ and /k'/ these seem to pattern particularly well according to morphological environment, that is, strong ejectives in stems and weak ejectives in prefixes. At the same time, /č'/ and /tr'/ in particular can display characteristics of either model, such as seen below in figure 3.13. This example of /č'/ has a small gap after frication and before voice onset, and a short amount of laryngealization. Thus, these results also agree with the interpretation of Hargus (2007) that "weak" and "strong" ejectives are merely two extremes and examples can fall along a continuum.

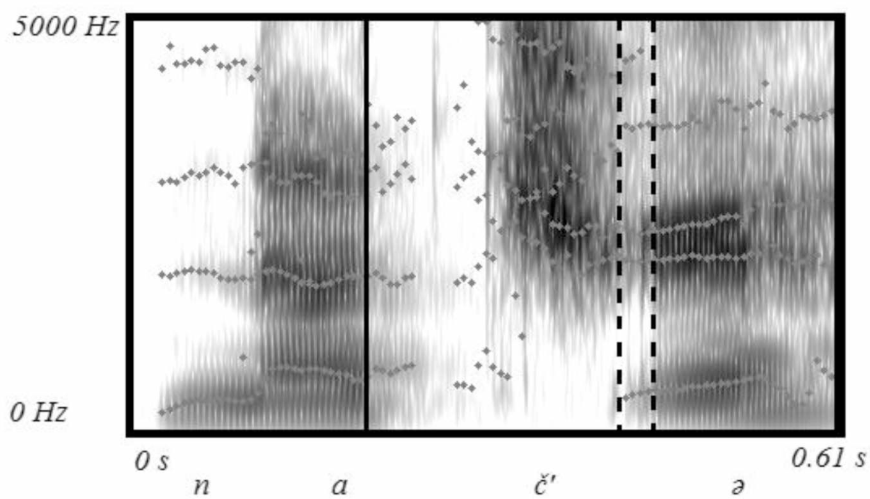


FIGURE 3.13: EXAMPLE OF A NEITHER STRONG NOR WEAK EJECTIVE:

Beginning syllables of nač'əʔàw 's/he is eating'

The most important observation that has emerged from this data, however, is that the source of most, if not all, ejective variation is due to duration differences in the particular phoneme. Moderate to strong correlations between an ejective's closure duration and its rise time have been calculated for all four ejective phonemes investigated in this study (although more tokens of /tr'/ are needed for a fully significant p value), as seen below in table 3.4. What this says is that if an ejective is allotted enough time for production, its release is clean: the glottis can achieve full closure and is able to re-open and allow strong vocal cord vibration, usually reaching modal voice quickly. If the ejective must be made in a shorter space, the glottis is not able to close as tightly and laryngealization occurs, as features of the ejective and following vowel are blended.

TABLE 3.4: CORRELATION BETWEEN CLOSURE DURATION AND RISE TIME

	Correlation Coefficient	**P Value**
/t'/	-0.574	0.033
/k'/	-0.62	0.008
/č'/	-0.537	0.024
/t^{r}'/	-0.568	0.087

Figure 3.14 below shows the correlation a stop's between closure duration and the rise time of the following vowel for the ejective /k'/. This chart shows the significant negative correlation between these two variables.

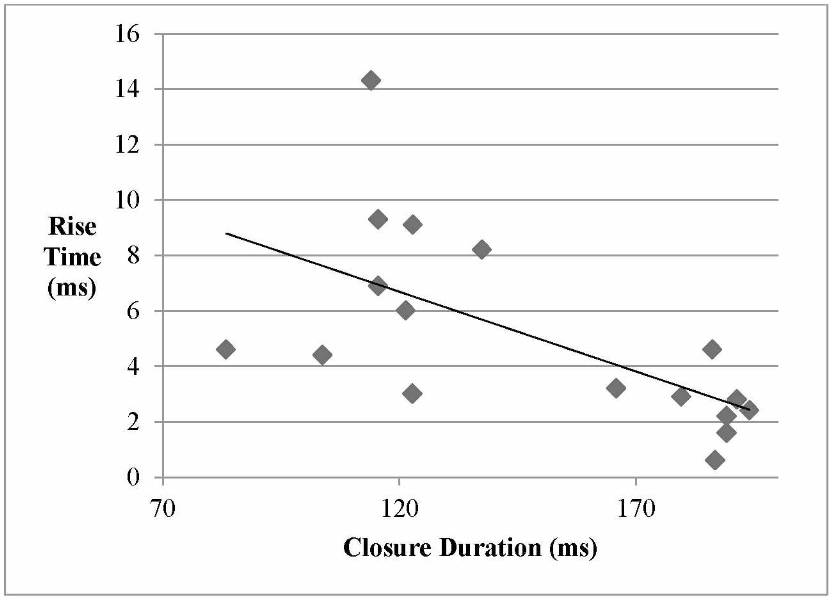


FIGURE 3.14: /k'/ CLOSURE DURATION TO RISE TIME CORRELATION

Additionally, sounds such as affricates by their acoustic nature necessitate a longer release since the fricative portion of the sound must be placed between the burst and the vowel onset. In anticipation of this extra time between burst and voice onset, the glottis has sufficient time to situate itself for a complete closure and then during this frication, prepare for modal voice vibration. It thus comes as no surprise that affricates pattern much differently with voice onset quality according to morphological environment, although all phonemes studied here show differences in closure duration. These observations support the findings of Bird (2002), in which "unadorned" ejectives like /t'/ and /k'/ were described as weak as opposed to affricates which were described as strong, although duration and morphological environment were not considered in that study.

To further corroborate the assertion that duration is the primary cause of ejective variation, we can examine a few outlier cases that initially appeared to be skewing the data. A few cases of /t'/ in stems were initially considered that had a preceding /n/, such as /nint'ey/ 'our strength. This and a couple others displayed a "mid" type ejective with a short amount of creak compared to the VOT, but with a very high rise time (gradual onset of modal voice). However, the adjacency of two stops, as was also suggested in §3.1.3.3.2., caused at least the second to be shorter (and probably both, but data from syllable coda position was not analyzed). The shorter duration of the /t'/ thus caused the laryngealization and the high rise time, correlating just like the rest of the data, although skewing the prefix vs. stem difference in closure duration and the expected rise time of the following vowel. Thus, while morphology provides a great deal of duration difference (shorter duration of prefix segments and longer duration of stem segments), it is not the only source of duration influence.

3.3. Comparison Between Pulmonic Stops and Ejectives. Although pulmonic stops and ejectives display fundamental acoustic differences, there are many similarities in how they pattern as a whole according to morphological environment. All phonemes (/n/, /d/, /t/, /č/, /ǰ/, /t'/, /k'/, /č'/, and /tr'/) displayed morphologically conditioned differences in the realization of either closure or release duration. For pulmonic stops, only those without a significant release (/n/ and /d/) exhibited closure duration increases in stem onsets while the affricates and the aspirated /t/, had significant higher VOTs in stem onsets. All ejectives had shorter closures in prefix onset position, while the non-affricates /t'/ and /k'/ showed particular contrast in patterning as weaker-type ejectives with laryngealized voice onsets in prefixes. For all stops however, the duration increase in stems is not high enough to consider those allophones to be doubled in length, and this duration difference is often not readily apparent.

3.4. Conclusion. Once again, the morphological environment, either stem or prefix, has demonstrated considerable influence in determining the duration of onset segments, with stem onset stops being significantly longer and more prominent. Depending on the acoustic properties of individual phonemes, this duration increase in stems may be found in the closure or the release, or both. This duration increase is also the source of a great deal of the variation in ejectives, while shorter duration is seen to correlate with an increase in creakiness. While morphological environment is typically the strongest contributing factor in a consonant's duration, phonetic environment (such as preceding other consonants) can also influence a segment's duration. Together, effects investigated in this study, such as longer stop duration and stronger type ejectives, are considered to be part of the larger system of stem prominence in the Hän language.

Chapter 4 Vowels

The Eagle dialect of the Hän language has seven monophthongs, /a æ e o i u ə/, a handful of diphthongs, and phonemic nasalization and tone (see more about Hän vowels in §1.4.2.). The vowel /ə/ is known to contrast sharply in prefixes as opposed to stems in both quality and duration (Krauss 1983). Other vowels may show morphologically conditioned duration differences as indicated by one orthographical practice (Krauss 1983). Following such observations, this study will compare the duration and quality of vowels in stems and prefixes, to investigate whether vowels display prominence in stem syllables.

4.1. Background and Literature Review.

4.1.1. Historical Development of Vowels. Proto-Athabascan had a total of seven vowels, four of which are considered full, /a· e· i· u·/ and three considered reduced vowels /ə ʊ ɑ/ (Leer 1979). The four reconstructed full vowels are considered longer and often pattern differently in the daughter languages. The Eagle dialect of the Hän language still preserves this seven vowel contrast, although some of these vowels have shifted. Additionally, mergers in certain syllable types have occurred, and diphthongs have developed as a result of stem final consonant loss. There is also no clear synchronic patterning still following the historical full and reduced vowel distinction. In the modern language, only /ə/ would be considered "reduced" due to its more extreme reduction in prefixes (see §4.3.1.).The table below (4.1) shows the general correspondences between the PA vowels and those of modern Eagle Hän.

TABLE 4.1: REFLEXES OF PA VOWELS IN MODERN HÄN (KRAUSS & GOLLA 1981)

PA vowel	Modern Hän
*/iˑ/	/i/
*/eˑ/	/e/
*/aˑ/	/æ/
*/uˑ/	/u/
*/ə/	/ə/
*/ɑ/	/a/
*/ʊ/	/o/

4.1.1.1. Merger of /ə/ in Dawson Hän. The Dawson dialect seems to have lost the separate /ə/ phoneme in stems altogether (Krauss 1999). Both dialects have merged /ə/ with /a/ before /t/ and possibly with /i/ before /k/ (de Reuse, p.c.).

4.1.2. Synchronic Observations of Hän.

4.1.2.1. Duration. According to some sources, Hän has both long and short vowels (Krauss 1983, Ritter 1978b). As a result of this interpretation, the Eagle or Alaskan orthography for Hän uses double letters for long vowels and single letters to indicate short vowels. However, according to this practice it would seem that this short versus long distinction is in fact morphologically conditioned, so that all stems with open syllables have long vowels and short vowels appear more or less everywhere else. Additionally, some claim (1978b) that there is contrasting vowel length in stem syllables with final glottal stops, that is CVʔ versus CVVʔ. From my own observations it seems the final glottal stop in CVVʔ is optional, and more importantly is only conditioned by low tone (almost all syllables with a final glottal stop in Hän have low tone, see Krauss

2005 for more on the development of tone in Athabascan). Thus, such syllables really only contrast phonemically as Cv̀ʔ versus Cv̀. Despite this, the Eagle Hän orthography writes long vowels in open stems, which might suggest these vowels are at least phonetically, if not phonemically, longer. The table below (4.2) shows the different syllable types in Hän and how they may relate to vowel length.

TABLE 4.2: VOWEL DURATION IN VARIOUS SYLLABLE TYPES (RITTER 1978B)

Syllable Type	Examples	Eagle Orthography
CVC (consonant final)	-/gòt/ 'knee,' /tθək/ 'caribou fence'	*-gòt, tthök*
CVV (open, stems only)	-/na/ 'mother, -/trə/ 'cry'	*-naa, -tröö*
CVʔ (glottal final)	-/čæ̀ʔ/ 'father', -/kèʔ/ 'foot'	*-chà', -kè'*
CVh (final h)	/t'əh/ 'cottonwood,' /k'oh/ 'fog'	*t'öh, k'oh*
CV (prefixes only)	/ni/- 'our', /tr'ə/- 1PLR subj.	*ni-, tr'ë-*

4.1.2.2. Quality. Some linguists have observed differences in vowel quality according to syllable type. For example, /a/ is described as having a quality more like [ʌ] in consonant-final syllables, as opposed to [ɑ] elsewhere (McRoy 1967, Krauss 1983). The similarity of [ʌ] to [ə] has caused a merger of /ə/ and /a/ before /t/. My own impressionistic observations also indicate /o/ having a schwa offglide before /t/, perhaps an intermediate stage between [o] and the diphthong [wa] as it occurs in Gwich'in cognates. Other phonemes, such as /i/ and /u/, sound slightly more central than [i] and [u] in consonant final syllables, but not necessarily occurring as [ɪ] or [ʊ]. For the purposes of this study, accurate measurements of vowel quality according to syllable type is unnecessary, however, awareness of the possibility of these variations is essential for making sure to control the syllabic environment for accurate evaluation of stem prominence.

A more relevant variation in quality, however, is what occurs in stem and prefix /ə/. For this paper I have simply referred to this phoneme as /ə/ as it is also in proto-Athabascan; however, phonetically it has a large range of possibilities. In open syllables, this vowel is especially unique among Athabascan languages and is most often described as being a front or central rounded vowel (McRoy 1967, Ritter 1978b, de Reuse 2006). McRoy (1967) states that /ə/ “has variants [ø] and [ɨ]; [ø] is a back-central, high-mid vowel, with associated rounding in the mouth rather than with the lips (?); [ɨ] is a low-high, central, slightly rounded vowel.” It is unclear exactly what her statement about rounding entails. Krauss (1983) writes that in stems and closed prefix syllables, /ə/ “is a mid central vowel, lips in a neutral position… in open syllables in prefixes, however… this vowel sounds very much like [a schwa].” Furthermore, the table below (4.3) shows different linguists and transcribers with their descriptions of the vowel in various environments, which may suggest different impressions of the vowel’s rounded and exact quality. In some cases, such as Marsh (1956), it is not absolutely certain if the characters transcribed match modern IPA, so for instance, it is not clear if the vowel [ɤ] is necessarily mid back unrounded, as the symbol would suggest in modern IPA.

TABLE 4.3: DESCRIPTIONS OF HÄN /ə/ IN DIFFERENT SYLLABLE TYPES

	CVV (stems)	CVk	CV (prefixes)
Marsh (1956)	[ɤ]	[ɪ]	[ʌ], [ɪ], rarely [ɤ]
Ritter (1978b)	[ø]	[ɨ]	n/a
de Reuse (2006, 2010, 2011)	[øː], [œː] (front rounded), [ə], [ə̥],or [ï] (central unrounded) (also the central rounded [ɵ], p.c.)	[ɨ] or [ə]	[ə] or [ɪ]

Following the description of Krauss (1983), Eagle Hän orthography follows a pattern of writing <ë> in open syllable prefixes and <ö> everywhere else, even in closed prefix syllables. Thus, according to both the descriptions and suggestions from the orthographical practices, it seems likely that /ə/ displays a difference in phonetic quality conditioned by the syllable environment, with the quality of /ə/ being different in open syllable stems as opposed to open syllable prefixes.

4.1.3. Observations in Other Athabascan Languages.

4.1.3.1. Vowel Lengthening as the Result of Stem Prominence. A few studies of Athabascan languages have indicated vowel lengthening in stems. Tuttle (2005) finds that in San Carlos Western Apache, vowels in final position (presumably being mostly stems, unless suffix syllables were included) are longer (344 ms) than those in non-final (presumably mostly prefixes) position (178 ms). Tuttle (2008) compares duration of the short vowels in Ahtna, finding a significant increase in the length of short vowels in stems as opposed to short vowels in prefixes. Stem short vowels averaged 83.7 ms compared to just 67.7 ms in prefixes. Hargus (2007) finds a similar trend in the Witsuwit'en language. Stem short vowels in Witsuwit'en averaged 83 ms compared to 62 ms in prefixes.

4.2. Methodology. This study measured the quantity and quality of vowels in Hän and compared these measurements in stem and prefix onset position. Due to the potential effects of syllable structure on vowel length and quality, only vowels in the same syllable types were compared. Only a sampling of vowel phonemes, particularly the ones that occur more frequently in both stems and prefixes, were compared. The first part of this study looks specifically at the reduced vowel /ə/, which is found to be the most radical in its morphological conditioning. /ə/ was compared in the syllables /Cə/ and /Cək/. Only full vowels in open syllables were considered for comparison; these included /Ce/, /Co/, and /Cu/.

Vowel duration is often easily defined by the presence of voicing when the surrounding consonants are voiceless. In the case of surrounding voiced fricatives, the vowel was judged to begin when high frequency frication ended and the formants became well-defined. Vowels were distinguished from surrounding sonorants by when formants became more intense and stable. However, when it was too difficult to neatly separate segments, the token was not included in the data. All examples were taken within sentences to maintain a normal speech rate; however, vowels in sentence-final position were not included due to their tendency to be lengthened. Also, examples were not included if there was a long pause between words, that typically coincided with a longer preceding vowel. For quality, F1, F2, and F3 were measured for /ə/, in order to investigate its possible rounding; only F1 and F2 were measured for the full vowels. Formant measurements were taken as averages of the most stable portions of the vowels, due to the effects of preceding and following consonants; if the surrounding segments appeared to affect the vowel too radically to determine a "stable" part of the vowel, the token was disregarded.

All examples were recorded from the speech of a single fluent speaker of the Eagle dialect of Hän, which retains the vowel /ə/ in stems. Recordings were made with a Zoom H4n Handy Recorder at a sampling rate of 44.1 KHz. Praat version 5.2.13 (Boersma & Weenink 2009) was used for acoustic analysis. A two-tailed t-test was applied to the data when needed to analyze variance. A p-value of .05 or lower was considered to indicate significance.

4.3. Results.

4.3.1. Reduced Vowels (/ə/).

4.3.1.1. Duration.

4.3.1.1.1. Open Syllables. Duration of the phoneme /ə/ in open syllables was found to be drastically different in stems as opposed to prefixes. Prefix /ə/ in open syllables averaged just 107.53 ms. Stem /ə/ as a whole had an average duration of 324.3 ms (p-value <0.001).

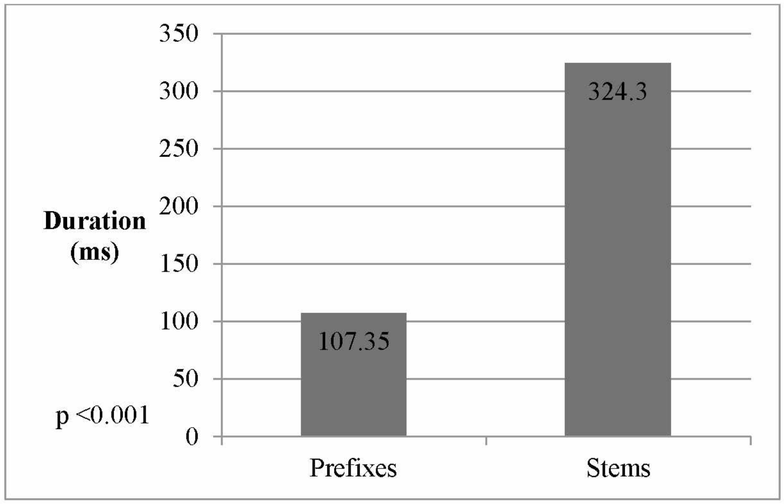


FIGURE 4.1: COMPARISON OF /ə/ DURATION IN OPEN SYLLABLES ACCORDING TO MORPHOLOGICAL CATEGORY

Figure 4.1 shows a drastic difference in vowel length of /ə/ in prefixes and stems in open syllables. Stem /ə/ averages about three times the duration of prefix /ə/ in this data.

4.3.1.1.2. Closed Syllables (CVk). The syllable type CVk is fairly common in both stems and prefixes in Hän, (as a prefix in */ək.tsey/* 'I am making X,' or as a stem syllable in */ho.dək/* 's/he is telling a story') and thus was useful for comparison of closed syllables. This comparison is particularly important since open syllable stems have no segments following them within words, as opposed to prefixes which are followed by the consonant of the following syllable. Nevertheless, vowel length still patterned as expected, although the difference was less drastic than what was observed in open syllables. The phoneme /ə/ in prefix CVk syllables averaged 78.9 ms as opposed to 116.2 ms in stems ($p < 0.001$).

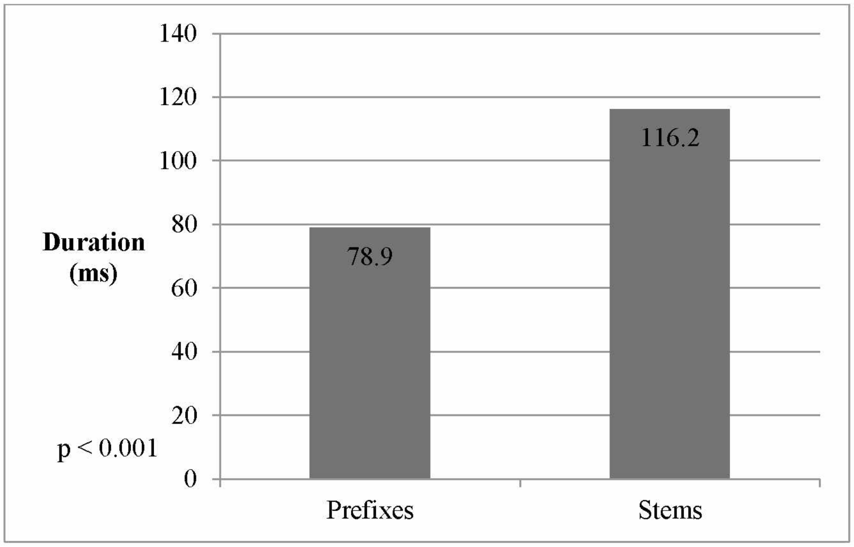


FIGURE 4.2: COMPARISON OF /ə/ DURATION IN CLOSED SYLLABLES (CVk) ACCORDING TO MORPHOLOGICAL CATEGORY

Figure 4.2 shows that the duration of /ə/ in prefixes is only 67.9% the length of those in stems, which, although significantly different, is a much less drastic difference than seen in open syllables, where stem variants were about three times as long. It is thus difficult to say whether syllable type conditioned the shorter vowel in CVk stems, and thus that the vowel was less subject to the extreme duration difference as seen between stem and prefixes in open syllables or if the segment final position of /ə/ in open stems caused additional lengthening of what we expect to find as a result of stem prominence; but in either case the effect of the morphology on duration is clear.

4.3.1.2. Quality.

4.3.1.2.1. Open Syllables. The phonetic quality of /ə/ also varied significantly in its production in stems and prefixes. Measurements were taken for F1, F2, and F3. F1 of stem /ə/ averaged 480.9 Hz compared to 558.4 Hz in prefixes, significantly different ($p < 0.001$). What is perhaps even more relevant to the difference in realization of these two morphologically conditioned allophones is the comparison of standard deviation. Standard deviation of F1 was 72 Hz in prefixes compared to only 19.9 Hz in stems; in other words, prefix /ə/ had a wider possible range in F1 and its height was probably more affected by surrounding segments. F2 of stem /ə/ averaged 1674 Hz compared to 2107 Hz in prefixes ($p < 0.001$). This likely indicates that stem /ə/ was more rounded than prefix /ə/, rather than the vowel was more central in stems (although it could indicate either or both). The morphologically conditioned difference of F2 was even more pronounced than for F1 since none of the values for stems or prefixes overlapped. Standard deviation of F2 was actually higher in stems (118.3 Hz compared to 135.8 Hz in prefixes), but these two measurements were not as radically different as what was observed for F1. There was no significant difference in F3, with both stem and prefix /ə/ averaging around 2830 Hz.

4.3.1.2.2. Closed Syllables (CVk). The vowel quality of /ə/ in closed syllables (ending with /k/ in all examples in this study) was significantly different from that of /ə/ in open syllables, primarily in its F2 measurement, where it was found to be pronounced further forward or less rounded. However, it did not show much morphologically conditioned difference in vowel quality. F1 of /ə/ in closed syllables was not significantly different between stems and prefixes, averaging 488.7 Hz in prefixes and 493.7 Hz in stems ($p = 0.74$). F2, likewise, was not significantly different, with an average of 2343.3 Hz in prefixes and 2374.7 Hz in stems ($p = 0.49$). F3 was also not significantly different. Figure 4.3 shows the average F1 and F2 values for closed and open syllables containing /ə/ in both stems and prefixes.

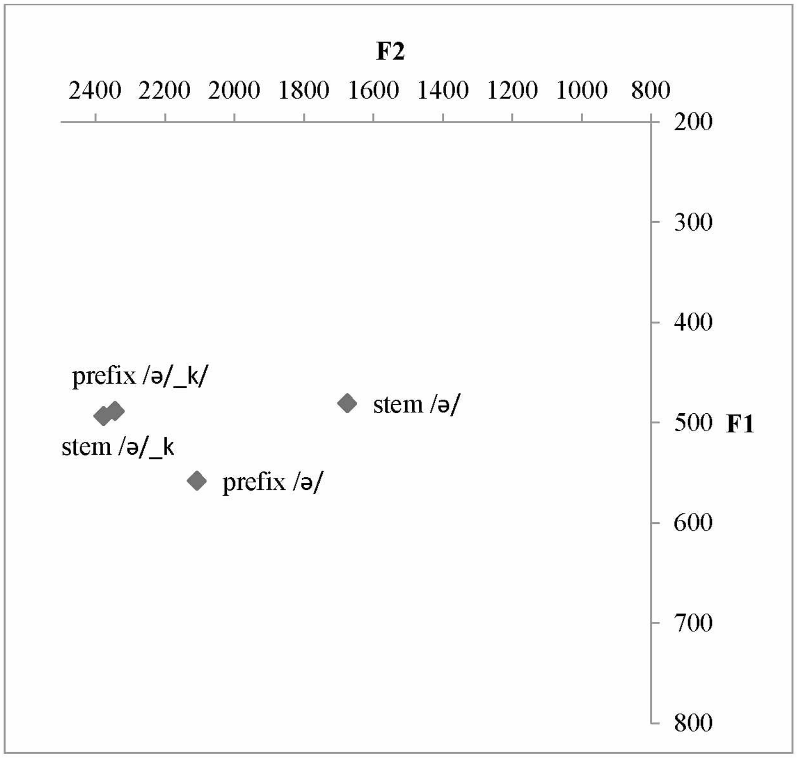


FIGURE 4.3: COMPARISON OF /ə/ VOWEL QUALITY ACCORDING TO SYLLABIC AND MORPHOLOGICAL ENVIRONMENT

Figure 4.3 shows once again the sharp contrast in vowel quality of /ə/ in open syllable stems and prefixes, compared to that of closed syllables, where no significant difference in vowel quality was measured. This is somewhat similar to the results for duration, where open syllables displayed a much more contrastive difference as a result of the morphological conditioning.

4.3.2. Full Vowels. Modern Hän has full vowel monophthongs, /æ a e i o u/, despite the fact that historically /a/ and /o/ were reduced vowels in Proto-Athabascan. This study of full vowels investigates only four of these, /e i o u/ as they pattern in open syllables according to morphological environment.

4.3.2.1. Duration. Results for duration differences of full vowels for indicating stem prominence were mixed. Although the vowels in stems were always longer, only the back vowels /o/ and /u/ were significantly longer in stems in the data collected in this study. The chart below in figure 4.4 shows these values in comparison along with their p-values.

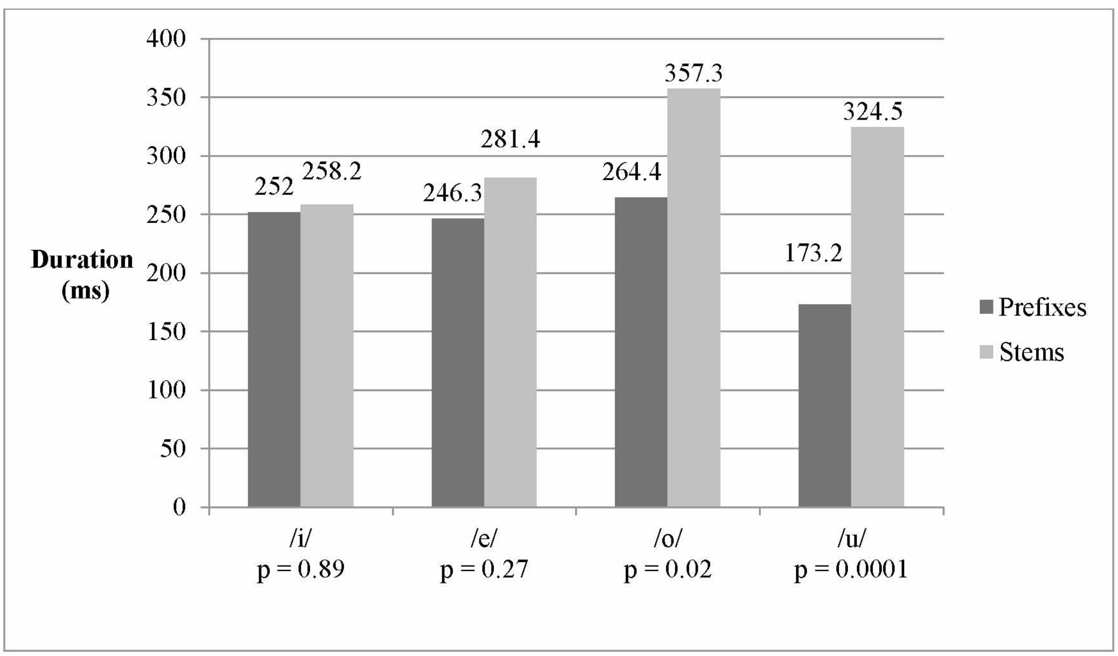


FIGURE 4.4: COMPARISON OF FULL VOWEL DURATION ACCORDING TO MORPHOLOGICAL ENVIRONMENT

4.3.2.2. Vowel Quality. Results for quality of the full vowels yielded few significant differences, and no overall trends were established for indicating stem prominence in the realization of vowel quality. The following figures 4.5 and 4.6 show the data for vowel quality averages (F1 and F2 respectively) with their p-values. F1 of /i/ and F2 of /e/ were found to be significantly different in stems and prefixes, however for both phonemes, there was a high frequency of palatal stops before the stem variants, which could very possibly have an effect on the following vowel.

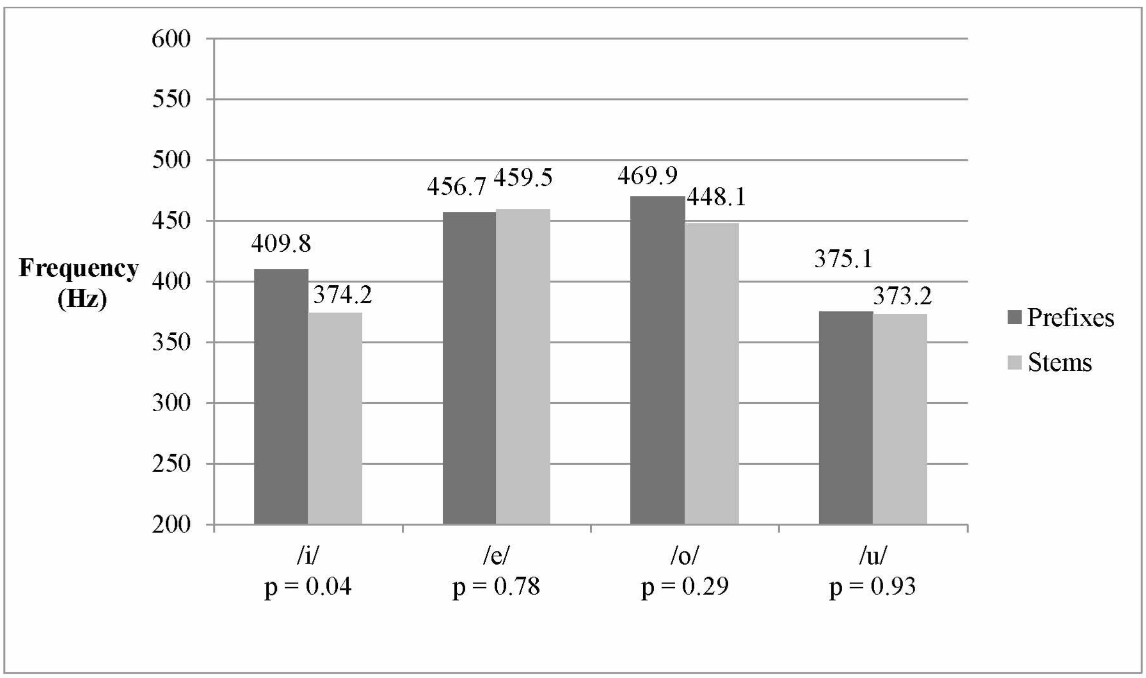


FIGURE 4.5: COMPARISON OF F1 OF FULL VOWELS ACCORDING TO MORPHOLOGICAL ENVIRONMENT

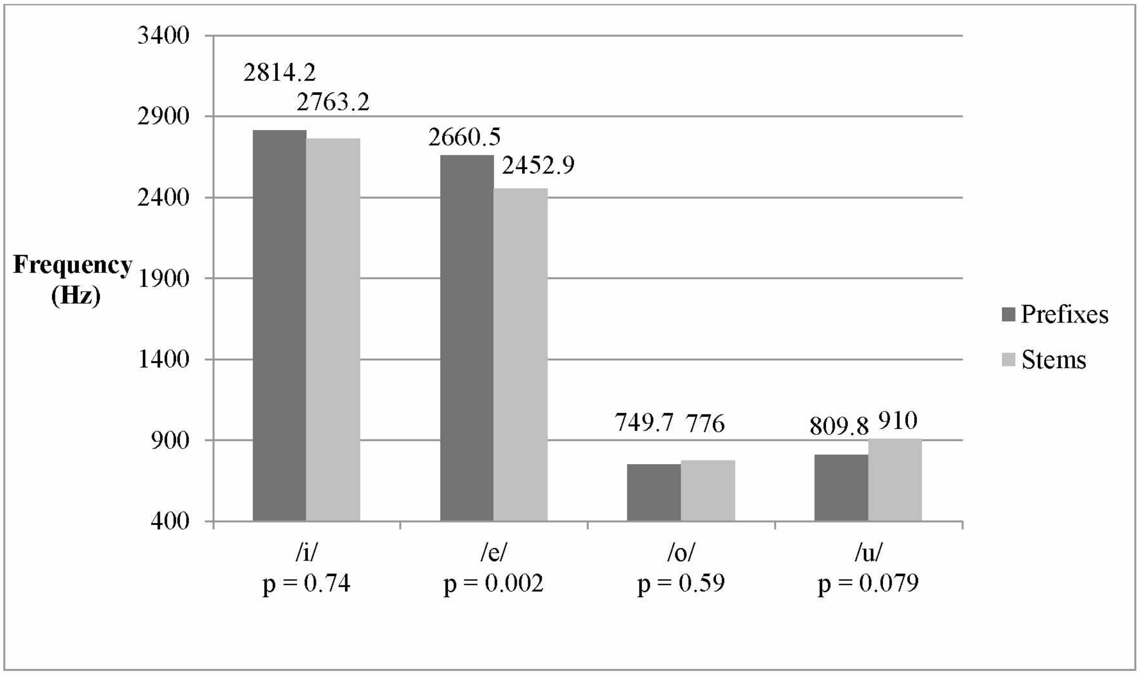


FIGURE 4.6: COMPARISON OF F2 OF FULL VOWELS ACCORDING TO MORPHOLOGICAL ENVIRONMENT

4.4. Analysis.

4.4.1. Duration. For the reduced vowel /ə/, the duration difference between stems and prefixes is profound, particularly so in open syllables and statistically very significant in both closed and open syllables. This is not the case for the full vowels investigated in this study. As seen in figure 4.4, while stem variants were longer on average, this morphological conditioned difference was only significant for /u/ and /o/. The inconsistency of this data may suggest there is another uncontrolled variable affecting vowel duration. My own impressions corroborate this theory, as some prefixes seem longer in duration than others. This variable is most likely stress. As there has been no thorough description of stress in Hän, it was impossible to remove this variable from the data without first conducting a separate study to fully understand this phenomenon.

In studies of other Athabascan languages, duration is often an important correlate of stress. Tuttle (2003) finds that in Lower Tanana "duration is by far the most reliably significant acoustic correlate of stress" (327). Studies have also described stress in Athabascan languages as occurring on full vowels (Kari 1990, Tuttle 1998, Tuttle 2003, Hargus 2007), and rarely falling on reduced vowels (although it can if the conditions are just right). This would further explain why only the results for full vowels seem to be affected, since full vowels do seem quite capable of receiving stress even when occurring in prefixes. What is particularly interesting about this complication is the fact that stress did not have so great an effect on consonant production (as investigated in chapters two and three) to obscure the effects of stem prominence, unlike its possible effect on vowel production, indicating that such stress may be realized differently from stem prominence. Furthermore, stem prominence seems to be completely regular and does not fail to occur in any sort of environment: neither the preceding vowel (whether stressed, unstressed, full or reduced), nor the vowel or syllable weight of the stem seems to have any effect on stem prominence, which is entirely morphologically conditioned. Thus, although some accounts (Kari 1990, Hargus 2007) do not distinguish stem prominence and stress (while stem prominence could be considered stress at the morphological rather than word level), it needs to be studied as a separate phenomenon.

Example (4.1) shows a few examples of words to demonstrate where stress seems to fall impressionistically.

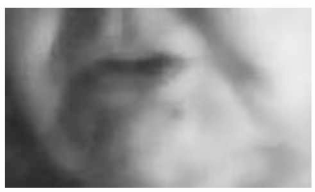
(4.1) Examples of Stress in Hän

a. /ɬe.ˌǰih.ǰə.ˈnì.**ðat**/ ‘they fell in love with each other’

b. /wə.ˈnè.**ðaw**/ ‘it was hot’

In (1a) there seems to be some, possibly secondary, stress on the syllable /ǰih/ and a little more, perhaps primary stress, on the syllable /nì/, despite the lower tone. The stem /ðat/ also receives prominence (longer onset consonant and vowel), so the effect is almost like a spondee in the last two syllables. In any case, the /e/ in the first syllable is unaccented. Compare this to (1b) where the /e/ sounds stressed. The first unstressed /e/ is only 159 ms, compared to 250 ms in the second example where it sounds stressed. In other words, there is preliminary evidence that stress effects vowels length, causing certain prefixes to become “prominent” but possibly in a different way from stem prominence as described in this paper.

4.4.2. Vowel Quality. Vowel quality differences in full vowels were mostly insignificant and inconclusive at best, considering more care should be taken to control the phonetic environment in future study. However, the reduced vowel /ə/ in open syllables displays a significant difference in quality, most radically in its F2 value. Attempting to translate these formant averages into a phonetic description can be fairly complicated, however. Based on the impressions of the researcher, /ə/ had a rounded quality in open syllable stems, and possibly in stressed prefix open syllable, somewhere between front and central, [ø] or [ɵ]. In prefixes and before /k/, the quality was less rounded, if at all, and more central, like [ɪ] or [ɪ̈]. The problem with obtaining an accurate description of this vowel from formant measurements is that F2 can be affected both by frontness/backness and roundedness. The figures below (4.7 and 4.8) are pictures which show the lips of the speaker saying the vowel /ə/ in the word /šahtsə/, 'mouse,' (rounded), and /hodək/, 's/he is telling (a story)' (unrounded). While the example in 4.8 is rounded, it should be noted this is not rounded as much as front rounded vowels in languages like French (de Reuse, p.c.).



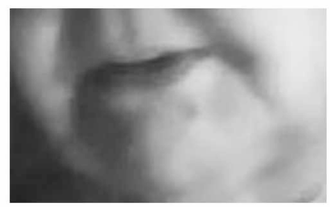


FIGURE 4.7: LIP ROUNDING IN /šahtsə/ FIGURE 4.8: LACK OF LIP ROUNDING IN /hodək/

It would make theoretical sense that the shortening of a vowel such as /ə/ might cause it to be produced more centrally, and possibly even less rounded. With shorter duration, there would be less time to achieve articulatory precision, so a certain bleaching of features could occur. However, producing a significant correlation between vowel duration and vowel quality proved fruitless with the current methods, particularly due to the fact that vowel centralization *or* rounding could cause a lowered F2 value, and in this data we may be comparing a vowel that is less centralized and rounded with one that is more centralized and unrounded (such as [ø] compared to [ï]). This was also the difficulty in providing quantitative data to describe the articulation of /ə/, particularly given the fact that it has been described as both back unrounded and front rounded (both of which could potentially have similar F1 and F2 values).

When all tokens of /ə/ are considered together (in both stems and prefixes and closed and open syllables) there is a -0.72 correlation coefficient between duration and F2 ($p < 0.001$). However, this may not be legitimate evidence of this relationship due to regular allophonic patterning (rounded, longer allophones are always found in open stems, for example). Correlations would also have to found within the separate environments to confirm this relationship. These correlations did not appear to follow any pattern, being either negative *or* positive and only in one case being significant. Closed stem /ə/, for example, displayed a 0.68 correlation between duration and F2 ($p = 0.02$). This could be interpreted as an increase in centrality or roundedness when duration is increased. Again, it is perhaps no surprise that these correlations are insignificant or erratic, since it is unclear whether F2 variability is due to centrality or roundedness, and it is unclear which allophones necessarily contain which features at any level. That is, is the speaker intending to produce /ə/ with rounding in prefixes, but is usually unable given the short duration, or is this allophone simply unrounded on all levels? Therefore, while this paper proposes the theory that there *is* a relationship between the realized vowel quality of /ə/ and duration, no clear, quantitative evidence can be provided to support or deny this claim.

4.5. Conclusion. This paper provides evidence showing the effects of stem prominence on duration and vowel quality. The reduced vowel /ə/ is much longer in open stem syllables than in prefixes, and is fairly longer in closed stem syllables as opposed to closed prefix syllables. The vowel quality of /ə/ in open stems is also much more distinctive, having a rounded, front or central quality such as [ø] or [ɵ]. In all other positions, where the duration is shorter, the vowel has a quality more like [ɪ̈] or [ɪ]. Full vowels were not conclusively shown to be longer in stems in this study. Although some significant results were obtained, it seemed there was at least some other variable, most likely stress, that was affecting vowel duration in prefixes. When stressed prefixes were identified based on the researcher's impression and removed from the data, significant but preliminary results were obtained which isolated the effect of stem prominence. Future acoustic research is needed to better understand the stress system of Hän. Vowel quality was also not shown to differ for full vowels in stems, although these results may also be skewed by the current lack of understanding of the stress system.

Chapter 5 Discussion

This chapter will review the results of all three studies within this paper and consider them in relation to each other. Contributions of this study and topics for future research are considered in §5.2. and §5.3.

5.1. Duration and Stem Prominence. In all three individual studies, which examined fricatives, stops, and vowels separately, the feature most regularly linked to stem prominence was duration. Each of these classes of sounds were found to be in some way longer in stems as part of the system of morphological prominence in Hän. Simpler segments like vowels, fricatives, and the nasal /n/, which were not composites of a closure and a release, were longer in total duration in stems. Stops, on the other hand, displayed lengthening either in their closure or in their release (whether aspiration or frication in affricates). Figure 5.1 shows the proportional length of different segments examined in this study in prefixes to their length in stems, indicating the feature found to be significantly different (for stops).

As the chart indicates, fricatives, plosives, ejectives, and vowels are all significantly shorter in prefixes. Consonants in prefix onsets were between 60% and 90% the length of those in stem onsets. Only two of the full vowels were found to be significantly shorter in prefixes, in which case they were about half to three-quarters as long; this was much different from the reduced vowel /ə/ which in prefixes was only

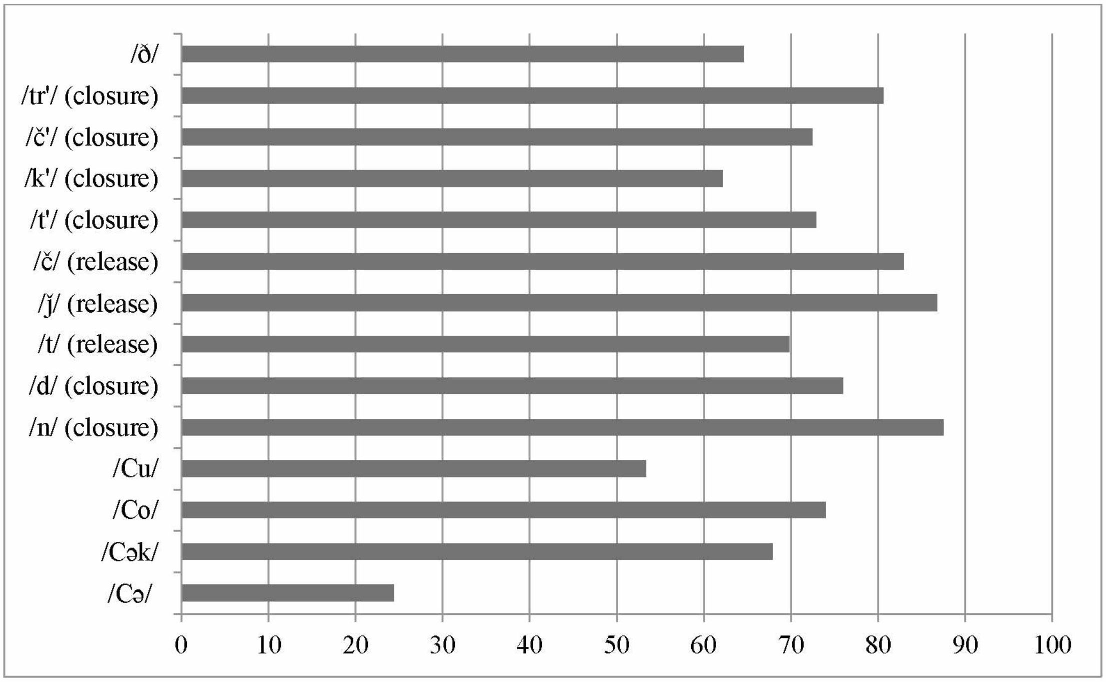


FIGURE 5.1: PERCENT LENGTH OF PREFIX SEGMENTS COMPARED TO STEM SEGMENTS

about one-quarter as long as when it occurred in stems. Examples of the phoneme /ə/ in closed syllable prefixes were not as drastically different as those in stems, being about two thirds the length.

5.1.1. Correlates of Duration. In each separate study, covering fricatives, stops, and vowels, there were additional acoustic features that characterized either prefixes or stems. For example, fricative voicing (for voiced fricative phonemes) was realized differently in stem and prefix onsets, with stem variants more often displaying semi-voicelessness. Prefix onset ejectives were often “weak” type ejectives, with very little gap between the burst and voice onset, which more often displayed a laryngealized quality than in stem onsets. Vowel quality of /ə/ was also significantly different in prefix nuclei, being more central and less rounded, although it was difficult to determine the exact articulation of such allophones from quantitative measurements alone.

Because the morphological conditioning of duration was consistent across all types of sounds, correlations between duration and other conditioned effects were considered. In addition, both fricative semi-voicelessness in stems and post-ejective vowel laryngealization in prefixes are qualities realized along a continuum and also were not always displayed as expected according to morphological environment, making it difficult to call these completely predictable allophones. For example, recall from §2.3.2. that some examples of semi-voiced fricatives in prefixes occurred, and that examples of post-laryngealized ejectives were found in stems (§3.2.3.3.1). The reduced vowel /ə/ does seem to have predictable allophones in stems and prefixes, however. It seems possible, instead, that another feature, such as duration, which itself can be quite variable, might be influencing the realization of these qualities.

On theory alone, a hypothesis of a correlation between duration and voicing percentage, voice quality, and vowel quality appears to be logical. With less time to produce a sound, it might be realized in a weaker or sloppier manner, and different realizations of this "sloppiness" would be specific to each set of sounds. With more time to produce a sound, certain features might become exaggerated, embellished, or it could be more difficult to sustain certain qualities throughout such lengthening. Voicing in longer fricatives, for example, might fade out during longer duration, considering the energy it takes to produce voicing during a high degree of articulatory obstruction such as in fricatives. Shorter ejectives would have sloppier releases, with the preceding ejective and following vowel “blending” to produce a laryngealized voice onset. A more prominent reduced vowel, such as in stems, might gain extra “color” with a feature such as rounding, or might lose some rounding and become more centralized if spoken more quickly.

Significant correlation coefficients were also calculated to support these theories. For example, fricatives displayed a complex relationship between duration and voicing. For sibilant voiced fricatives, there was actually a positive correlation between voicing and duration, which was unexpected, and tokens were never completely voiced. For the non-sibilant voiced fricatives, the shortest examples tended to be fully voiced, while the remaining semi-voiced tokens did not as a whole display a correlation between voicing and duration. Ejectives also demonstrated higher rise times when shorter (rise time being an indication of how quickly a vowel achieves full voicing, thus low rise time often indicates laryngealization). The data for the vowel /ə/ did not produce a significant correlation between duration and F2 (the formant found to be most different between stem and prefix allophones) for each individual allophone. However, as was explained in §4.4.2., F2 can be lowered either by a vowel moving further back in the mouth *or* by an increase in rounding. Since prefix allophones are considered to more central (and articulated further back in the mouth) and *less* rounded, this combination of effects on F2 is unclear.

It is important also to note that a correlation between two variables does not necessarily imply causality. For example, we could consider the possibility that voicing could affect the duration of a fricative, or rise time could affect the duration of an ejective. It is also possible that another unknown variable could be causing both correlates. However, given the regularity of significantly longer segments in stems for all types of sounds and that the secondary features displayed as a result of this morphological conditioning could logically be affected by duration, it seems plausible that duration displays some degree of causal relationship with these secondary features.

5.2. Contributions of This Study. The results and analysis of this study provide several contributions both to the field of phonetics and Athabascan linguistics. The results of this study suggest that duration can affect the realization of different types of segments. Such duration itself is part of a larger system of stem prominence, demonstrating the link between morphological structure and phonetic realization. Such synchronic observations also lend insight to the workings of language change by providing acoustic data that indicates early stages of allophonic patterning (such as semi-voiced fricatives and weak ejectives, neither of which are completely predictable, unlike the patterning of /ə/ and possibly semi-voiced fricatives in Tanacross (Holton 2000)). Additionally, the acoustic data in this study provides detailed descriptions of sounds that pattern in ways that are not well understood in an under-documented language.

This study also provides several new insights to the field of Athabascan linguistics. Although many studies have described stems as receiving some sort of prominence (Kari 1990, Tuttle 2005, Rice 2005, Leer 2005), this study unites several observations into a single system. Thus, morphologically conditioned phenomena such as post-laryngealized ejectives occurring more often in prefixes and semi-voiced fricatives occurring more often in stems are both considered to be influenced by duration. In many ways, these synchronic observations are seen as a continuation of diachronic developments of stem fortition, and serve to witness the development of morphologically conditioned allophony. This study focuses only on stem prominence, and not stress, which is different from past studies. By better understanding stem prominence, and eventually the stress and tone system of Hän and how these all interact, future research resulting from this study will help document these unique processes at work in Athabascan prosody.

5.3. Future Research.

5.3.1. Stem Prominence and Other Prosodic Systems. Future research will investigate the interactions between stem prominence and other prosodic systems such as stress, tone, and intonation. In both the study of fricatives and the study of stops, significant results were obtained that suggested morphological conditioning, where word stress was not considered, and consonant tokens were obtained from prefixes that may have been either stressed or unstressed. In the study of vowels, however, the data suggested that some vowels in prefixes may have been displaying prominence (and were possibly stressed), behaving similarly to vowels in stems (which were found to always displayed prominence). Further investigation is needed to understanding the system of stress, at which time the effects of stem prominence and stress can be isolated.

5.3.2. Duration and Disyllabic Stems. Duration may also provide clues that suggest the underlying morphology in words. For example, if we expect longer consonants in stem onset position, then what would we expect in disyllabic stems, and could this give insight as to whether such a stem is analyzable? Would each syllable of a stem such as /ǰəǰe/ 'man' or /t'əga/ 'girl' act like a stem, or would only the first, or only the second? In both cases, the /ə/ patterns as in prefixes, being a more centralized and less rounded allophone, so it appears, perhaps superficially, that these words would both be analyzed as a prefix plus a stem. However, there is some phonetic evidence to suggest this is not the case, and rather, that these words act as a single morphemes. For example, figure 5.2 shows the words /ǰəǰe/ 'man' and the analyzable /ǰəǰæ/ 'his friend,' that is, the prefix /ǰə/, 'his' plus /ǰæ̀/, 'friend,' next to each other in the same sentence. In every case, there was a noticeably longer closure in the second /ǰ/ of /ǰəǰæ̀/, where there was a morpheme boundary, than in the second /ǰ/ in /ǰəǰe/, where there was no morpheme boundary.

Additionally, a preliminary analysis shows a difference in closure length between the /g/ in /agak/ 's/he is running,' and /t'əgæ/ 'girl.' The /g/ in /agak/ is in the stem onset of a word with two morphemes, and its closure averaged 184.4 ms as opposed to only 84.2 ms in /t'əgæ/. Although speakers may be able to analyze the second syllable /gæ/ as 'little,' this data may suggest there is no morphological process occurring to produce this word. Further study may help provide further clues for understanding the morphological structure of Athabascan words by measuring these differences in duration.

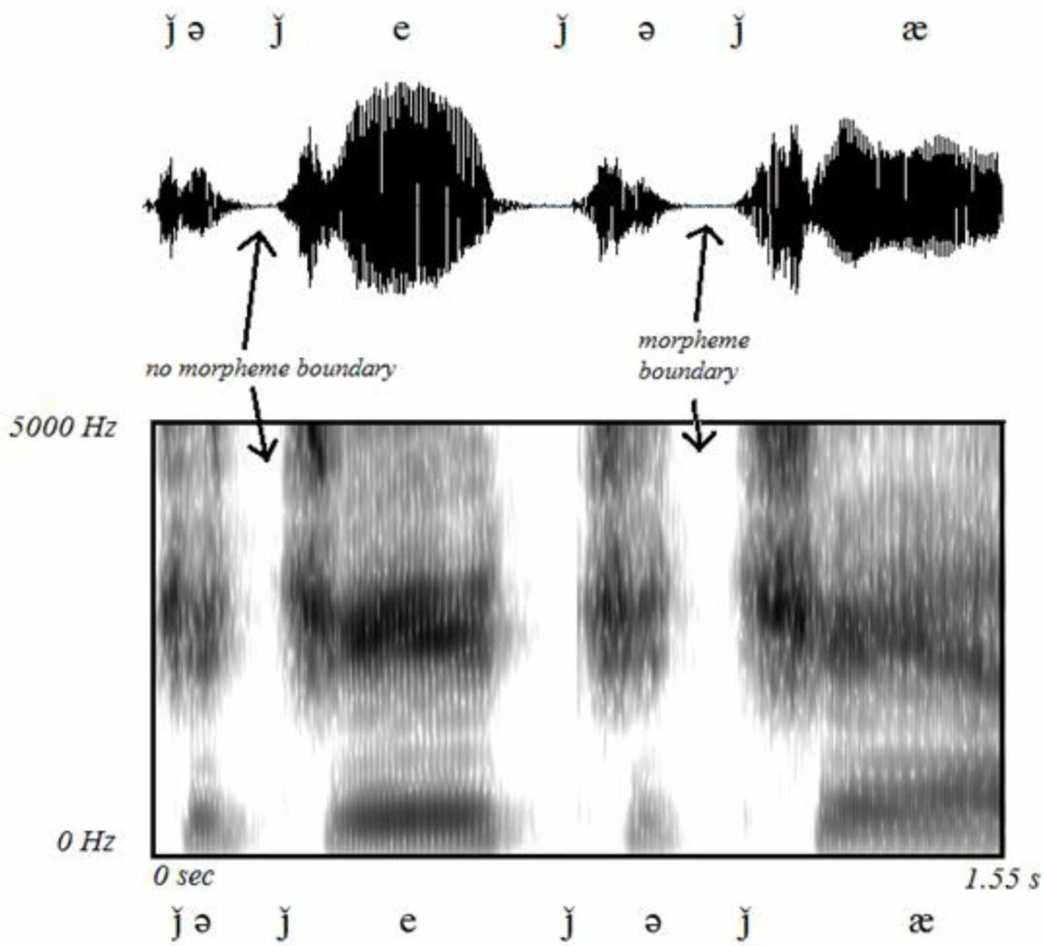


FIGURE 5.2: DURATION DIFFERENCES BETWEEN DISYLLABIC STEM AND POLYMORPHEMIC WORD

5.3.3. Multiple Morphological Layers. The synchronic observations of this paper along with innovations brought about by diachronic morphological conditioning indicate that some of the processes involved affected segments in different layers of morphology, and not necessarily following a dichotomous stem versus prefix distinction. For example, fricative voicing and lenition only occurred in certain prefixes, particularly those further to the right (closer to the verb stem) in the template (see §2.1.1.4.) This might indicate either that there are either additional morphological layers or categories besides just stems and prefixes that might condition a phonological process, or that different morphemes may have been historically classified in different ways (such as disjunct prefixes patterning as stems at some point in history). Additionally, the patterning of /ə/ is also at odds with that of the consonants in stems that might be considered disyllabic, as shown in §5.3.2. While /ə/ patterns like a prefix in words like /ǰəǰe/ 'man' or /t'əgæ/ 'girl,' perhaps indicating a prefix plus a stem, the consonant length of intervocalic /ǰ/ and /g/ in these examples suggests they are not in stem onset position, and that the entire words might be single morphemes. It is unclear whether vowels pattern differently from consonants with respect to morphology or if these allophones of /ə/ are simply relics that allude to an earlier stage where such words were analyzable as two separate morphemes. Likewise other probable disyllabic stems such as /ǰəžar/ 'cow moose' demonstrate the interaction of several possible phonological processes. Again, it would appear like a prefix /ǰə/ plus a stem /žar/ not only because of the /ə/ but because of the voiced fricative /ž/ which usually occurs as /y/ in prefixes. It is unclear without further study, however, if this /ž/ would be shorter or more voiced than that in a word such as /ǰəžar/ 'her own son,' however it is clear it is not a /y/ as we might expect to find when not in stem onset position. If such fricatives in disyllabic stems are not in fact shorter, then they would be patterning differently than the intervocalic stops in words like /ǰəǰe/ and /t'əgæ/.

Further study should also investigate whether relative degrees of prominence are displayed in conjunct and disjunct prefixes, as well as in incorporated stems as opposed to surrounding prefixes or the primary stem. Using some of the patterns found in this study and others can also serve to better understand these layers of morphology, by alluding to the underlying and historical structures of words and understanding their synchronic structures.

5.3.4. Future Improvements in Methodology. Improvements in the methodology of this study may also help obtain more accurate results. Developing means to normalize the data might make trends and correlations stronger. Features such as duration and intensity were often relative to the speaker or the particular sentence. Better understanding of how the F2 of vowels is affected by rounding and backing will also provide a means for determining the correlation between vowel quality and duration.

5.4. Conclusion. The findings of this paper have described many of the different effects that can occur as a result of morphological conditioning. Fricatives tend to be realized as semi-voiced in stem onsets, while ejectives are often followed by vowel laryngealization in prefixes. Vowel quality can also pattern according to morphological class, with /ə/ occurring allophonically as something like [ø] in open stems and [ï] elsewhere. All segments tend to display some sort of increase in duration in stem onsets. This duration, due to its regularity in all types of segments and correlation data, is believed to be the source of many of these secondary effects including semi-voicelessness, laryngealization, and vowel reduction. Further study will utilize methods of normalization along with a better understanding of other prosodic systems such as stress, tone, and intonation to strengthen these findings further.

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Appendix. Hän Practical Orthography

Symbols used in this paper	IPA (phonetic)	Alaskan Orthography	Canadian Orthography	comments
/b/	[b] or [p]	<b>		The speakers in this study did not have a separate set of voiced stops so these were not represented differently.
/d/	[d]	<d>		
/ǰ/	[dʒ]	<j>		
/d/	[t]	<d>		
/dð/	[tθ][1]	<ddh>		
/ dł/	[tł][1]	<dl>		
/dz/	[ts][1]	<dz>		
/dr/	[tʂ][1]	<dr>		
/ǰ/	[tʃ][1]	<j>		
/g/	[k]	<k>		
/ʔ/	[ʔ]	<'>		
/t/	[t^{h}]	<t>		
/tθ/	[tθ^{h}]	<tth>		
/tł/	[tł^{h}]	<tl>		
/ts/	[ts^{h}]	<ts>		
/tr/	[tʂ^{h}]	<tr>		
/č/	[tʃ^{h}]	<ch>		
/k/	[k^{h}]	<k>		
/t'/	[t']	<t'>		
/tθ'/	[tθ']	<tth'>		
/tł'/	[tł']	<tl'>		
/ts'/	[ts']	<ts'>		
/tr'/	[tʂ']	<tr'>		
/č'/	[tʃ']	<ch'>		
/k'/	[k']	<k'>		
/θ/	[θ]	<th>		
/ł/	[ł]	<ł>		
/s/	[s]	<s>		
/sr/	[ʂ]	<sr>		
/š/	[ʃ]	<sh>		
/x/	[x]	<kh>		
/h/	[h]	<h>		
/ð/	[ð]	<dh>		

/l/	[l] and [ɮ]	<l>		two morphologically conditioned allophones
/z/	[z]	<z>		
/z^{r}/	[ʐ]	<zr>		
/ž/	[ʒ]	<zh>		
/ɣ̥/	[ɣ̥]	<gh>		
/w/	[w]	<w>, <-ww>	<w>	
/y/	[j]	<y>, <-yy>	<y>	
/r/	[ɹ]	<r>, <-rr>	<r>	
/l/	[l]	<l>, <-ll>	<l>	
/m/	[m]	<m>		
/n/	[n]	<n>, <-nn>	<n>	
/ŋ/	[ŋ]	<ng>		
/w̥/	[w̥]	<hw>, <-w>	<hw>, <-wh>	
/j̊/	[j̊]	<-y>	<-yh>	
/r̥/	[r̥]	<-r>	<-rh>	
/l̥/	[l̥]	<-l>	<-lh>	
/n̥/	[n̥]	<-n>	<-nh>	
/a/	[a]	<ä>		
/æ/	[æ]	<a>		
/e/	[e]	<e>		
/i/	[i]	<i>		
/o/	[o]	<o>		
/u/	[u]	<u>		
/ə/	[ə], [ø], [ɪ]	<ë>, <ö>	<ë>	at least two allophones, possibly absent in stems in Dawson dialect

1 The fricative portions of the plain affricates may be at least partially voiced (de Reuse, p.c.)

Shaded boxes indicate phonemes that all speakers may not have